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Handbook on Citrus Fruits Cultivation and Oil Extraction
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Citrus fruits are produced all around the world. They contain healthy nutrition content that works wonders for the body. Citrus fruits act as a fabulous source of vitamin C and a wide range of essential nutrients required by the body. India only represents a mere 4% of global citrus fruit production. But now a day, there is a rise in its cultivation. This rise in citrus production is mainly due to the increase in cultivation areas & the change in consumer preferences towards more health & convenience food consumption & the rising incomes. Citrus fruits have long been valued as part of a nutritious and tasty diet. The flavours provided by citrus are among the most preferred in the world, and it is increasingly evident that citrus not only tastes good, but is also good for people. It is well established that citrus and citrus products are a rich source of vitamins, minerals and dietary fiber (non starch polysaccharides) that are essential for normal growth and development and overall nutritional well being. However, it is now beginning to be appreciated that these and other biologically active, non nutrient compounds found in citrus and other plants (phytochemicals) can also help to reduce the risk of many chronic diseases. Appropriate dietary guidelines and recommendations that encourage the consumption of citrus fruit and their products can lead to widespread nutritional benefits across the population. All citrus fruit is acid fruit. The acid fruits are the most detoxifying fruits and excellent foods. Lemon oil is obtained from the fruits of citrus Limonum, Risso (Rutaceae). Although the majority of commercially available essential oils are extracted from the original botanical material by use of steam distillation, most citrus essential oils are extracted by pressing the rinds of the citrus fruits. The oil of sweet orange is obtained from the fruits of citrus Aurantium Risso and the oil of bitter orange from fruits of citrus Bigaradia Risso (Aurantiaceae). Orange Essential Oil is energizing and is usually well loved by men, women and children. Citrus fruit oils are cheaper than most other essential oils. Lemon or sweet orange oils that are obtained as by products of the citrus industry are even cheaper.

Some of the fundamentals of the book are botanical classification, classification of genus citrus, criteria for citrus classification, information on important citrus fruits, subgenus fucitrus (edible citrus fruits), citrus cultivation, citrus fruits, kinnow mandarin, citrus fruit breeding, soil inspection for citrus family, nutrition for citrus world, proper harvesting of citrus, post harvesting of citrus fruits, etc.

This handbook on citrus fruits provides relevant information on most citrus crops, the basics of citriculture & production, pre & post harvest management, picking, storage etc. Selected topics on oil extraction of citrus fruits are also given to provide knowledge of the techniques used. This book will be helpful for technocrats, farmers, research scholar, institutions etc.

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General Control Measures

39. Nematodes of Citrus
Citrus Root Nematode
Tylenchulus Semipenetrans Cobb. 1913
Host Range
Control Measures
Cultural Control
Biological Control
Resistant Rootstocks
Reniform Nematode (Rotylenchulus Reimformis)
Burrowing Nematode (Radopholus Similies)
The Lesion Nematode (Pratylenchus Coffeae)
Root-knot Nematode (Meloidogyne Africane)
The Lance Nematode (Hoplolaimus Indicus)
Poncirus
Fortunella (Kumquats)
Citrus

Sample Chapter:
Botanical Classification

Citrus fruits are members of the Rutaceae family which contain more than a thousand species mostly found in the tropical region of Africa, South East Asia and Australia.

Generally the three related genera Poncirus, Fortunella and Citrus are

Classification of Genus Citrus

Classification of citrus fruits is a very problematic one which awaits still a perfect solution agreeable to one and all. Many scholars have made attempts to group the numerous species of Citrus in some sort of orderly arrangement but failed in their attempts. Says Most of these classifications instead of elucidating the problems with which they dealt have only made them more complicated. Each classification had its own limitations and drawbacks.

Early attempts by Europeans have resulted in very simple classifications limiting the entire group of citrus fruits to about a half a dozen species in one genus. Such classifications not only grouped such diverse forms as limes and citrons in one species but give a species standing to different forms closely related to each other and left out entirely a large number of fruits unknown to them. They mainly depended upon the herbarium specimens of citrus fruits. They had no acquaintance with the places where citrus fruits originated. The various problems faced by the systematic pomologists are enumerated below:

Instead of taking the citrus fruits as they found growing at present many scholars have based it on imagination how they have been thousands of years ago.

Very few scholars had a personal knowledge of the whole region in which the species have originated and being grown many have seen only those which are grown in the West.

Many of the characteristics on which classifications are commonly based are not constant within the species as new forms seem to occur more frequently.

The high frequency of bud sports or mutations also cause inconvenience in the classification.

The species of genus citrus being easily crossable within and without a number of interspecific and interfemen hybrids increased. But these hybrids the products of two or more heterozygous parents tend to segregate in the next generation thus the taxonomist is at loss to classify them. Though many scholars have exonerated the hybrids as species however Singh accepted them as valid species by questioning the validity of giving a species status to Prunus domestica a hexaploid.

There is no general agreement about what constitutes the species. According to earlier botanists a plant should be given a species rank on the basis of occurrence of its wild forms. Others stressed that a species should represent a definite unit sufficiently different with any another unit notwithstanding the presence of its wild forms history and different geographical distribution.

Variation in popular names as well as in botanical names makes the problem more complicated.

Diversity of forms in genus Citrus and their localisation in the world add to the chaotic condition. Some of the citrus fruits are so localised in certain parts that they are hardly known outside their native homes.

Criteria for Citrus Classification

Taxonomists have employed different criteria for classifying citrus fruits. The important characters on which classification was based are elucidated below:

Plant characters: Hardness to cold height habit mode of branching foliage nature of thorns roundness of branches pubescence.

Leaf characters: Shape size thickness apex margin colour vines wings articulation aroma of crushed leaf and pubescence of leaf.

Floral characters: Sex solitary or crowded size of peduncle pedicel size of flower pubescence
colour  shape of calyx  division of sepals  stamens free on united  nature of anthers  ovary size  shape
colour  style size  nature of stigma  fragrance of flowers and nature of inflorescence.

Fruit characters:

External characters: colour  shape  size  surface  base of calyx  areole  persistency of style.

Internal character: Nature of rind (thickness  firmness and adherence)  density of oil glands  colour of
glandular layers  taste of mesocarp  number and size of carpels  pulp  colour and texture  size and shape
of juice vesicles  closely or loosely packed  arising from dorsal or radial side of carpellary wall  presence
or absence of acid oil  axis  hallow or solid  juice taste  quality amount and flavour  sugar and acid
content  seeds  number  size  shape  colour cotyledons  colour  nature of embryo  whether
monoembryonic or polyembryonic  number of embryos.

Miscellaneous characters: Fruiting season  quality rank  general and horticultural importance and uses.

Different Classification

Though more than a dozen of scholars not only in U.S.A. and Japan have attempted to classify citrus
fruits  only the works of Swingle and Tanaka are noteworthy. Tanaka was the erstwhile student of Swingle
and after leaving Swingle he did much independent work and made a valuable contribution to the Citrus
classification. After Swingle and Tanaka  In India scientists have classified the citrus fruits of Assam. Of
Late Singh by taking the advantage of Swingle's and Tanaka's treatments has attempted to classify citrus
fruits and evolved a key for the identification of different citrus fruits.

The basic difference between Swingle and Tanaka is their independent outlook about what constitutes the
species. Swingle followed the traditional views about the species rigidly and rejected most forms
considered to be of hybrid origin and lack of wild forms. He called such of those species of doubtful validity
which may be a natural species of comparatively recent origin or may be a chance hybrid or sport as
satellite species. His classification was considered as a conservative type and he was considered as a
lumper .

On the other hand  Tanaka's treatment of 1954 is elaborate. He reiterates that a species should
represent a definite unit sufficiently different from another unit. He has given a species rank to every form
showing a slight difference. By such a liberal attitude and approach he has arrived to a figure of 145
species  while Swingle recognized only 16 species and 8 botanical varieties of genus Citrus. Thus they
represent two extremities in Citrus classification.

Workers made a critical study of both Swingles and Tanaka's treatments of citrus fruits. He observed that
former's approach to the problem is not comprehensive (i) that it does not adequately cover the forms of
horticultural importance (ii) that numerous ancient oriental forms of citrus for instance Indian  Japanese
and Chinese were ignored (iii) that the approach denies species standing to many ancient well known
and distinctive forms for example Rough lemon  Rangpur lime  Palestine sweet lime  Satsuma
mandarin etc. (iv) that treatment of certain distinctive forms led to complication speculation besides
being cumbersome for example Rough lemon was said to be a hybrid of Citrus limon  Palestine sweet
lime as a hybrid of C. aurantifolia  King mandarin as a hybrid between mandarin and sweet orange (v)
that consistency is wanting (a) separate species standing is sanctioned for obviously closely related forms
for instance pummelo and grapefruit  sweet and sour orange (b) at the same time separate species
standing is denied to forms which obviously differ much more for instance all mandarins in one species
all true limes in one species and the lemon like forms all in one species.

While in the case of Tanaka's system others observed (i) that the system contains an excessive number
of species for example 35 species with mandarin group alone: (ii) that it is hard to justify the number of
species as differences so minor as scarcely detectable are considered for giving species standing (iii) that
numerous cultigens some of doubtful validity were also granted species rank (iv) that species standing
was given to certain natural hybrids or forms of doubtful justification (v) that approach appears to be unnecessarily complex and detailed.

We have studied some of the little known citrus fruits of India during 1959-62 and recorded his observations and opinions. Hodgson observed wide variations in Rough lemon (C. jambheri Lush.) and amilbed (C. megalaxycorpa.) moderate variations in attani (C. regulosa Tanaka) considerable variations in Rangpur lime (C. limonia Tanaka) galgal (C. pseudolimon Tanaka) Karna (C. Karna Raf) gajanimma (C. pennivesiculata Tanaka) and limited variations in sweet lime (C. limettioides Tanaka). Several distinct forms of the above species were recognised with respect to tree, leaf, flowering, bearing and fruit characters. Most of the forms described by Bhattacharya and Dutta (2) were found identical to one or the other species studied. Scientists felt that species standing was justified in the cases of Rangpur lime, Rough lemon, sweet lime, galgal Kharna Khatta Kichili gajanimma attani Indian wild orange and Khasi papeda but were doubtful of the justification of granting species rank to adajamir of Assam, amilbed, sadaphal and sat Kara. They opined it would be justified if adajamir of Assam is treated as botanical variety of gajanimma of South India C. pennivesiculata var assamensis and sat Kara as botanical variety of C. macroptera C. macroptera var. annamensis.

Of late Singh felt a need for a compromise between Swingle's and Tanaka's classification of Citrus. With this approach he has accepted citrus forms of hybrid origin as valid species. He has accepted the subgenus Papeda of Swingle and has divided the subgenus Eucitrus into 8 groups which correspond closely to the 7 sections of Tanaka. The major deviation from Tanaka's classification is that citron and true lemon have been put under two separate but related groups. Tanaka has accommodated these under sub-section Citriodes and Limonoides under section Citrophorum. In the present treatment lemons have been split under two groups. The lemon, citron of the Bojoula type (C. limonimedica Lush) which resembles the citrons in the bushy habit, serrations and rumpling of leaves, persistent style, flower characters and continuous flowering habit have been grouped along with citrons and the true lemons (C. limon Burn) of the tree type with solid core, flowering once a year and thin, caducous style have been put under the Limoid group along with Rough lemon (C. jambhiri lush) and Hill lemon or Galgal (C. pseudolimon Tanaka). This has facilitated the relationship between the last 3 species.

Information on Important Citrus fruits

**Subgenus Fucitrus (Edible Citrus Fruits)**

Includes all the cultivated citrus fruits. Pulp vesicles are free from acid droplets, filled with pleasantly acid subacid or sweet juice. Petioles wingless or slightly winged, stamens cohering in bundles.

The following are the important fruits in Eucitrus:

**Acid Group**

*Citrus Medica Linn. (Citron)*

Commonly considered to be indigenous to India. Singh reports the distribution of many types of citron all over India. Probably citron is the first citrus fruits to reach Europe. Romans found it growing in Media and Persia hence the name Citrus medica. Jews called it Etrog and made use in their rituals. It is mainly grown for its peel. Citron is most sensitive to frost.

A shrub or small tree with a short indistinct trunk and short thick, irregular, thorny branches. Thorns sharp, short, leaves large not articulated, oval oblong with serrate margin, rounded apex, dark green above lighter beneath, petioles without wings, flowers large, axillarily, in compact clusters of 3-10, often unisexual, calyx small, cupped, corolla white within, tinged with purple on the outside, stamens short 40-45 in number, pistil large, ovary 9-12 loculed or more, fruit lemon yellow, large, oblong, rough or warty, sometimes ridged, apex blunt, pointed, rind thick, white except for the outer coloured rind, core
hallow  pulp sparse  juice scant  acid or sweet  juice sacs small  slender  seeds oval  plump  numerous  monoembryonic.

**Citrus Lemon Burm (Lemon)**

Origin of the lemon is a mystery. Most of the authors agree on one point that South Eastern Asia is its natural home, but dispute whether India can exclusively claim as its home. Since no wild forms of lemon were found in India, Bonavia concluded that it originated in Malaya, quoting Rumphius saying that Malayans call all citrus fruits by lemon and that Malaya may probably be the home of lemon. Hayes stated that lemon is commonly said to be indigenous to India. Hodgson states that the lemon must have originated in the eastern Himalayan region of India and adjoining areas where citron also originated for natural hybrids with citron and lemon characters are found abundantly there. Dutta proclaim that in the light of the above it is not unnatural that the primeval forest of Assam where lemons of various kinds are found even today to grow in a wild state might be a probable home of lemon. However, it is upto the future research workers to decide upon this subject till such time. India, especially Assam may tentatively be said the home of lemon. Singh says that true lemons are not indigenous to India and the cultivars like Lisbon and Eureka are introductions in India. Lemon is sensitive to frost.

Small to medium trees with spreading growth habit with long round or angular thorny branches leaves evergreen alternate medium to large lanceolate sharp pointed with sub serrate margin light green petioles wingless flowers medium sized solitary in axils on distinct peduncles purple when young sometimes staminate by reduction calyx persistent corella large white in side purplish outside stamens 20-26 apparently free or sometimes united in bundles pistil densely dotted with oil glands ovary elevated on a prominent disc 7-10 loculed fruit ripens at all seasons ovoid or oblong and pointed at both base and apex light yellow surface smooth or rough rind thin yellow when ripe flesh light coloured juice abundant and acid juice sacs long and pointed core solid seeds few small oval quite smooth pointed at the micropylar end embryo white polyembryonic.

**Citrus Aurantifolia Swingle (Acid Lime)**

Includes Egyptian Indian and Mexican limes. Tanaka says it is a native of Malayan peninsula while Hume says it is native to India and South eastern Asia. It is widely distributed and naturalized in the tropics. Lime and lemon are usually confused and thought one and the same though both are distinct from each other. In habit of growth in the winged petioles in the clustered blossoms in the flavour of the fruit in their immunity from citrus scab the limes are in a class by themselves and quite different from the lemons.

A shrub or small tree of straggling habit with small stiff interlocking or drooping thorny branches thorns small sharp numerous young branches light green becoming darker with age leaves small elliptic oval orange like (hence the name) glossy green margin slightly indented petioles narrowly winged (similar to sweet orange) flowers small axillary in clusters of 3-10 bisexual faintly pink in the bud but fades easily calyx 4-5 pointed petals 4-5 fleshy stamens small 20-25 united into bundles ovary about 10 loculed fruits small greenish yellow round to oval frequently popellate peel very thin paper like (hence Kagzi from Kagaj meaning paper) and aromatic pulp greenish acid juice sacs small slender pointed seeds small oval pointed highly polyembryonic.

**Citrus Latifolia Tanaka (Tahiti or Persian Lime)**

It is a native of South Pacific. Botanically it closely resembles aurantifolia but physiologically it is quite different. It is as hardy as lemon. It is a triploid. It is more resistant to pests diseases and unfavourable conditions in general.

A large vigorous tree with fewer but thicker thorns leaves much larger and thicker somewhat different in form and much darker green flowers large and faintly coloured in the bud fading rapidly fruits solitary or in clusters large fruits often mistaken for small lemons seeds few or lacking apparently monoembryonic.
**Citrus Limettioides Tanaka (Sweet Lime)**

It is indigenous to India. An important rootstock in the near East and grown to some extent for the non-acid fruit. Tender to frost.

Medium to large spreading tree irregular in growth habit with fairly long slender thorns and new growth colourless leaves medium in size pale green and characteristically somewhat rolled or cupped petioles wing margin rather than winged as in other limes flowers moderately large and non-coloured fruits medium in size globose to ellipsoid generally with low flat papilla rind thin with distinct aroma surfacesome times very smooth flesh pale yellow juice abundant flavour insipid seeds medium in size cotyledons white highly polyembryonic.

**Citrus Jambhiri Lush (Rough Lemon Jambiri)**

Tanaka found this fruit scarce in eastern India though Bonavia collected it in the United Provinces. Dutta found at least six distinct forms of jambhiri in Assam and believed Assam as native place of jambhiri. Singh reports unlimited variation in the types of Rough lemon found in India. As such it can safely be concluded that Rough lemon is indigenous to India. It is one of the world’s principal rootstocks. It is fairly sensitive to frost.

Tree is medium to large with spreading growth habit less spiny than lemon leaves smaller round apex paler in colour marginal serration fainter flowers smaller faintly coloured in the bud petals less deeply coloured pistil sparsely granular dotted fruit lemon brown very different in form round compressed with fleshy apical papilla strongly developed cavity surrounding papilla rough irregular surface adherence of rind fairly loose and core open at maturity pulp yellow seeds numerous small highly polyembryonic.

**Citrus Limetta Risso (Limetta of the Mediterranean)**

Small to medium round topped tree of less vigour and more compact growth habit fruit small round shaped or depressed lemon yellow acid less at maturity. Its most distinctive features are the truncate apex with a strongly depressed circular furrow in the centre of which is a prominent fleshy papilla or nipple Polyembryonic.

There appear to be two forms which are identical with the exception of the colour factor (flowers and new growth). The form in which the colour is developed is commonly referred to as a sweet lemon and appears to be the lumia of the Mediterranean. The form which exhibits no colour development is often referred to as sweet lime and appears to be the limetta of the Mediterranean. Since they are both non-acid and differ only in the colour factor it seems best to assign them to the same species.

**Citrus Karna Raff (Kharna Khatta)**

It is indigenous to India it exhibits characters suggestive of the lemon and Rough lemon or possibly sour orange also. The leaves and flowers of this species are similar to those of Rough lemon but are larger in size and the petiolar wing is more prominent. As a rootstock it is widely used in India.

Medium to large tree of upright spreading growth habit spines thicker and larger than lemon new flush fairly coloured leaves large lemon like but broader and darker green petioles longer and more prominently winged flowers large tinged with red fruit orange coloured medium to large oval with well developed apical papilla surface rough and irregular rind thick adherence strong core open at maturity pulp orange juice plenty but sour moderately seedy cotyledons white moderately polyembryonic.

**Citrus Cultivation**

The nomenclature and distinction of the cultivars of Citrus is as problematic and confused as the classification of genus Citrus. The problem of distinguishing the different clones or clonal varieties on the basis of what constitutes a clone seems to be a simple one. However accidental mixtures will frequently
occur making it difficult to distinguish unless the variety in question is sufficiently distinct from others to be easily recognisable. Further no variety is likely to remain entirely static and unchanged over long periods no matter even if it is perpetuated vegetatively. The frequency of bud variations in Citrus seems to be high. Unless these bud variations are eliminated the cultivar will not remain pure and may become a heterogenous mixture leading to confusion.

Environmental factors manifest variation with respect to period of blooming yield potential etc. by which the plants within a cultivar show variation from each other demanding a separate identity. Clones propagated by buds taken from a selected individual are called bud strains. However the progeny of these bud strains from different trees of the same variety often exhibit differences detectable only by growing them in considerable number in close proximity adding further confusion to nomenclature. The presence of numerous hybrids also adds to the confusion of nomenclature. For the present it is best to segregate them based on their parentage like citranges (Trifoliate orange x sweet orange) tangelos (mandarin orange x pumelo) etc.

The local names also contribute their might to the chaos in the nomenclature and distinction of cultivars of Citrus. Descriptions of some important cultivars of Citrus are furnished in the following pages.

Sweet Oranges

**Citrus Sinensis Osbeck**

The cultivars of sweet orange (tight skinned orange) may be separated into several easily recognizable groups but within these groups there are large number of cultivars so similar that they cannot be readily distinguished.

Hume has arranged the cultivars of sweet orange into four groups: (i) Spanish oranges (ii) Mediterranean oranges (iii) Blood oranges and (iv) Naval oranges.

While Webber classified the cultivars into three large groups: (i) Those with normal fruits (ii) those with abnormal or navel fruits and (iii) the Blood oranges with red or red streaked pulp.

The most important cultivars of sweet oranges cultivated on a commercial scale in India are Malta Blood Red and Pineapple in Punjab Mosambi in Western India Sathgudi and Batavian in South India.

**Batavian**

The name suggests that it has come from Batavia.

The cultivar can hardly be distinguished from Sathgudi except in rind colour which is light yellowish green usually with pale yellow patches on the green rind in the case of Batavian. In Sathgudi axis is solid while in Batavian it is hollow. It is inferior to Sathgudi in quality.

This is mainly grown in coastal districts of Andhra Pradesh.

**Hamlin**

It originated in Florida and named after the owner of the grove in which it was found in 1879.

Fruit medium in size deep greenish yellow early in season changing to orange red with full maturity apex rounded and very slightly scarred base smooth rounded rind very smooth bright thin segments 11 12 uneven in size flesh deep orange yellow juice abundant acidity and sugars well lended flavour excellent seeds usually 1 5 but many fruits are seedless.

It is an early variety grown in Punjab Haryana Uttar Pradesh etc.

**Jaffa**

It belongs to Mediterranean group of Hume and to normal fruit group of Webber. It is from Palestine.

Fruit medium to large orange yellow to orange red globose to ellipsoid apex rounded base rounded
rind smooth  finely pitted  medium thick  oil glands medium in size  numerous  segments 9  12  flesh
yellow  fine grained  pulp melting  acidity and sweetness normal and well blended  flavour rich  quality
excellent  light orange  core small  seeds few 9  10.
It is a mid season variety  cultivated in Punjab  Haryana  and Uttar Pradesh.

Malta Blood Red
Blood oranges  so called due to the presence of red colour or red streaks in the pulp  have come from
Mediterranean region.
The tree dwarfish  compact  distinct in growth habit  abundant foliage  small oval leaves  rounded
almost wingless petioles. The fruit is medium to large in size  round or slightly long  cadmium yellow  rind
usually thin  tight and glossy  pulp streaked red early in the season and full red colour when ripe  fine
grained  melting  sweet and acidity well blended  juice abundant  T.S.S. 10 per cent rich in flavour and
excellent in quality.
This is a mid season variety  mainly under cultivation in Punjab  Haryana  Uttar Pradesh  Madhya
Pradesh and West Bengal.

Mosambi
The name has its origin from Mozambique  thence it was introduced into India.
Fruits small to medium  subglobose or elongated  surface smooth  with longitudinal furrows and the apex
marked with a circular ring (areole)  rind is marigold  thin  tight more difficult to peel  pulp apricot yellow
juice not plentiful  though sweet  sometimes almost insipid  owing to lack of flavour and inadequate
blending of acidity with sugars  contain 18  25 seeds. The colour of the rind remains green or yellowish
green under tropical conditions.
It is an early variety  cultivated mainly in Western India in states like Maharashtra  Gujarat.

Pineapple
Pineapple comes under the Mediterranean oranges of Hume and normal fruit group of Webber. The
Pineapple originated as a seedling in Citra  Florida. Due to its similarity of its flavour to that of pineapple it
was named as Pineapple. It is one of the leading sweet oranges under cultivation in United States.
The fruit is sub globose to round  medium sized  deep orange coloured when ripe  rind thin  tight
smooth  bright and glossy  finely pitted  apex rounded or slightly depressed or scarred  pulp is orange
yellow  abundant  melting  flavour rich  acidity and sweetness well blended  T.S.S. 9.5 per cent
excellent quality  seeds 13 to 24.
Mid season variety cultivated in Punjab  Haryana  Uttar Pradesh etc.

Sathgudi
Sathgudi is also called as Chinee orange. The name Sathgudi owes its origin to a place Sathgur in Tamil
Nadu.
Fruit almost spherical  small to large  smooth surface  attractively orange coloured when fully mature
base and apex evenly rounded  rind thin with little rag  semi glossy and finely pitted. Pulp uniformly
strawcoloured  juicy  flavour excellent  seeds few to many 12  20  segments 10  12.
In most places  the fruit does not develop proper colour as it is picked before fully ripe. It is seen in the
market from October to February. Sathgudi is mainly cultivated in southern districts of Andhra Pradesh and
Tamil Nadu.

Shamouti
It was placed under normal fruit group by Webber and not described by Hume. It originated in Palestine
during the early part of 19th century  probably as a bud sport or bud mutation from the Bellady orange of
Palestine and was introduced into U.S.A. in 1920.

Fruit ellipsoid size large orange to deep orange surface finely pitted but relatively smooth base evenly rounded rind thick firm and solid axis small solid or semi hollow segments usually 10 12 pulp light orange firm juice medium abundant flavour sweet and rich seedless.

It is a mid to late season variety grown mainly in Palestine.

**Valencia Late**

Hume grouped it under Mediterranean oranges while Webber placed it under normal fruits. Though this fruit was introduced from Europe to other countries its origin is not fully known. Lee and Scott evidently indicated China as the most probable place of origin thence it was introduced into Europe very early by Portuguese or Spanish voyagers.

Fruits medium to large round or slightly oval deep golden orange apex rounded slightly flattened scarred base smooth rounded rind thin smooth tough axis medium solid or semisolid sections 9 12 pulp orange coloured juice abundant melting acidity and sweetness well blended excellent flavour and quality seeds few 5 6.

It is a late variety grown in Punjab.

**Washington Navel Oranges**

It is grouped under Navel oranges. It is an important commercial orange of California. It originated near Bahia Brazil in the early part of the 19th century and was first imported from Brazil in 1870 into Washington from whence it obtained the name.

Fruit globose to obovoid or ellipsoid size large orange or orange yellow apex slightly protruded or broadly nippled navel medium to large enclosed to broadly open sometimes protruding base rounded or somewhat flattened rind smooth tough leathery medium thick segments usually 9 11 well defined flesh rather coarse deep orange yellow juice abundant pulp melting acidity and sweetness well blended flavour rich and quality excellent seedless.

It is an early variety found promising at Kodur Andhra Pradesh.

**Mandarin Oranges**

*Citrus Reticulata B.*

Loose skinned oranges belonging to species *Citrus reticulata* Blanco are commonly designated as mandarins. Though mandarin and tangerine are names used more or less interchangeably to designate the whole group tangerine is applied more strictly to those varieties producing deep orange or scarlet fruits. The differences between these two groups are very slight the main visible difference being the colour of the fruit usually considered varietal in magnitude. As such from the horticultural standpoint the Dancy and Beauty tangerins can be called as mandarins. This is easily said than done because these two names got firmly established in the world markets and cannot be easily erased.

Inspite of their close relationship and having many characters in common the mandarin oranges can easily be separated into rather distinct groups in fact certain investigators have proposed to recognize these groups as distinct species. As such King orange was given a name *Citrus nobilis* and Satsuma oranges are named as C. unshtu while Swingle considered them as natural varieties of mandarin oranges. Webber has separated the mandarin oranges into (i) King group (ii) Satsuma group (iii) Mandarin group (iv) Tangerine group (v) Mandarin lime group and finally (vi) Mitis group. However till the taxonomic investigations are completed it seems advisable to retain the name mandarin as group name to all the loose skinned oranges.

The most important mandarin in India undoubtedly is the Santra (*Citrus reticulata*) which includes varieties such as Nagpur santra Coorg Santra and Khasi orange.
Calamondin (Citrus Madurensis Lou)
Although Swingle recognised it as a valid species in 1914 he did not accord species rank. While Tanaka placed with the loose skinned orange group but retained its specific rank as C. mittis. It is very cold resistant for a true citrus fruit as hardy as Satsuma. It has been mentioned as a promising hardy stock in Texas for the lime.

Tree tall upright columnar rather bushy and dense slightly thorny leaves broadly oval lighter green below petioles short narrowly winged. Fruit colour orange to deep orange surface smooth and glossy very finely pitted shape oblate to spherical size small base flattened even or very slightly depressed apex markedly flattened and depressed rind thin loose easily separable when ripe tender and sweet oil abundant odour pleasant segments 7–10 pulp orange coloured juicy acid seeds few 0.5.

Clementine (Algerian Tangerine)
It is a tangerin. According to Trabut it is probably an accidental hybrid of the mandarin and the sour orange and originated in a garden in Algeria. Since it was found as a chance seedling the percentage is not known and believed simply to be a variant within the mandarin group. It was first introduced into the United States in 1909.

Tree size medium spreading nearly thornless somewhat willowy foliage dense leaves dark green above and lighter green below lanceolate petioles medium in length slightly winged if any fruit colour deep orange red surface smooth and glossy slightly pitted shape globose to elliptical size medium base evenly rounded to slightly necked basal area with radiating furrows apex depressed rind thick loose axis large and hollow segments 8–12 adherence slight pulp deep orange tender melting quality and flavour excellent seeds for 3–6.

It is an early variety.

Cleopatra (Spice Tangerine) C. reshni T.
Tanaka considers it as originated in China as it is identical with the Ponki a variety of Chinese origin which is used in Japan and U.S.A. as a root stock. The Cleopatra was introduced into Florida from Jamaica.

Tree thornless with dense top upright but inclined to be willowy leaves small fruits produced singly or in bunches fruit colour dark orange red shape oblate flattened at both ends irregular in outline size small rind rough thin loosely attached segments 12–15 small flesh orange coarse grained juice abundant acidity and sweetness normal quality good seedy about 20 or more.

Coorg Orange
It is the most important commercial variety in South India particularly grown on large scale in Coorg and Wynad tracts.

The trees are very vigorous and upright with compact foliage sparingly spinous. Fruits medium to large bright orange in colour oblate to globose in shape finely papillate and winkled glossy base necked or depressed with glandular ribs extending through the collar rind thin to medium soft adherence slight easily peeled segments 9–11 rag little pulp vesicles uniformly coloured texture fine and tender flavour good juice abundant deep chrome in colour acidity and sweetness well blended when ripe. Seeds 14–30 matures a little later than Nagpur Santra.

Dancy Tangerine
In the United States the Dancy is the best known and most highly prized of all the mandarin oranges. Dancy originated from a seedling in Florida.

Tree large nearly thornless upright in growth foliage moderately dense leaves broadly lanceolate large petioles medium very slightly winged. Fruit colour deep orange red to scarlet surface smooth glossy in age becoming bumpy and irregularly furrowed shape oblate to pyriform size medium base depressed or flattened apex moderately depressed rind thin easily separable when ripe tender and sweet oil abundant odour pleasant segments 8–12 pulp orange coloured juicy acid seeds few 0.5.
sometimes evenly rounded but mainly slightly or markedly necked apex broadly depressed rind thin leathery rough loose and easily separable axis large hollow segments 10 14 rag little pulp dark orange melting flavour rich quality excellent seeds 6 12.

It is a late variety.

**Desi Mandarin (Pathankot)**

This variety is mainly grown in the Punjab hills. It seems to have originated as a seedling. The tree is large with semi upright growth habit and compact foliage and spineless. Fruit ovoid to sub globose colour uniformly Cadmium surface pitted semi glossy and finely wrinkled base short necked and furrowed rind medium firmness soft adherence slight segments 7 10 rag little pulp vesicles uniformly genista coloured texture fine and tender flavour fair quite juicy deep chrome coloured slightly acidic seeds few 3 7.

**Khasi Orange**

It is the chief commercial variety of Assam and has many local names after the places of production. Three is generally medium to tall with an erect habit densely foliaged both thorny and thornless. Fruits depressed globose to oblate orange yellow to bright orange surface smooth glossy base even or obtuse occasionally short necked slightly ribbed rind thin soft adherence very slight or none segments 8 10 rag little to medium pulp vesicles uniformly orange coloured coarse very melting flavour agreeable juice abundant orange coloured. Sweetness and acidity well blended. Seeds 9 25 (usually 10 15).

**Citrus Fruits**

Citrus fruits rank third in area (2.44 lakh ha) and production (19.52 lakh tonnes) in India during the year 1984 85 (Report of the Working Group on Horticulture for Seventh Plan 1985 90). Citrus crops occupy about 9.62 per cent of the total area under various fruit crops and have about 8.21 per cent of the total production of fruits in India. Under citrus group many members are being grown but mandarins are the most important followed by sweet orange and limes. However in this chapter a brief account is also given on another three citrus fruits namely lemon grapefruit and pummelo. The sweet orange (tight skinned orange) commonly known as mosambi malta and sathgudi is an important citrus fruit of India. It is commercially grown in Maharashtra Punjab Rajasthan and Andhra Pradesh. Sweet orange is highly polyembryonic. The tree is medium to large in size. The shape of the grown up tree is roundish sometimes slightly upright. Leaf apex is slightly blunt petiole narrowly winged. Aroma of leaf is distinctly different from that of sour orange. The thorns are more of less marked. Fruit subglobose to oval in shape orange in colour and 6 8 cm diameter. Rind (sking) is tight. The pulp vesicles are sweet orange is tinged central core of the fruit is solid to semi hollow. The shape of the seed is very variable.

**Climate**

Sweet orange requires dry and semi arid conditions coupled with distinct summer and winter seasons with low annual precipitation. In general low humidity and severe winter result in good colour development and external appearance in fruits whereas high humidity favours thin skin and plentiful juice. Strong winds whether hot or cool are injurious and wind breaks are grown to protect the plantation. Under humid environment fruit turns insipid and also there is more chances of attack of the live parasites such as lichens and Loranthes under high humidity and rainfall sweet orange fruits have thin and smooth skin and more juice. However taste is superior under dry conditions. High temperature and high evaporation during flowering and fruit set result in low yields possibly by increasing flower and fruit drop and by reducing fruit set.
Soil
The sweet orange can be grown on wide range of soils but medium to light loamy soils rich in organic matter well drained having the pH range from 6 to 8 are suitable. Soil should be at least one metre deep. In shallow soils the trees remain stunted and die early for want of proper moisture and nutrients. Salinity has negative association with yield.

Cultivars
The following are a few important cultivars of sweet orange.

Mosambi
The origin place of mosambi is said to Mozambique. Fruit is small or medium subglobose or elongated in shape. The fruit has distinctive longitudinal furrows and bears a circular ring (areole) around and apical end (styler end). The rind is thin and tight and green or yellowish green in colour it is difficult to peel. Pulp is less juicy and flavour is not marked. The fruit contains about 15 to 25 seeds.

Mosambi is an early variety. It is extensively cultivated in Maharashtra.

Blood Red Malta
It is introduced from Mediterranean region. Tree is comparatively dwarf. Leaves are small and oval and almost wingless petioles. Rind is thin and tight. The colour of the pulp is streaked blood red when fully ripe juicy and sweet acidity is 0.5 per cent TSS 10 per cent flavour is pleasant. The fruit contains 5 12 seeds or no seeds. The fruits are sometimes dried on the tree due to physiological disorder.

Bloos Red Malta is a mid season variety. It is mainly grown in Punjab Haryana Rajasthan and Uttar Pradesh.

Sathgudi
It is also known as Chini or Chinese orange. It has its origin place in Sathgur in Tamil Nadu (India). Fruit is medium subglobose areole absent. Rind is medium thick smooth and finely pitted. The pulp is straw coloured juicy with good flavour. The fruit contains 12 20 seeds. This is a famous variety grown in Andhra Pradesh and Tamil Nadu. The fruits are available from October to February.

Pineapple
It has originated as a seeding in Citra Florida. The fruit is medium to large sized subglobose orange in colour. Rind is thin bright and glossy in appearance. Flesh is primrose yellow juicy sweet and having flavour like pineapple. The fruit contains about 12 25 seeds.

Pineapple is a leading variety of sweet orange in the United States. In India it is cultivated in Punjab Haryana and Uttar Pradesh. It is mid season variety. It ripens in the month of December.

Washington Navel
It is originated near Bahia Brazil and was introduced in 1870 into Washington (USA) therefore it obtained the name. The term Navel has been assigned to these oranges because the fruits having a rudimentary fruit embedded in the fruit apex. The fruit is globose to obovoid or ellipsoid size large colour orange yellow apex often slightly protruded or broadly nipped. Rind is thick surface moderately pitted. The pulp is medium juicy with excellent flavour seedless segments 9 11.

Washington Navel oranges are early maturing and found promising at Kodur (Andhra Pradesh) around Bangalore and Coorg (Karnataka). However in Punjab it is not successful because the fruits tend to develop granulation. Trees are sensitive to heat and arid conditions especially during bloom and fruit setting periods.

Jaffa
Jaffa is a variety of sweet orange from Palestine. It has wide adoptability. The fruit is medium to large sized globose to ellipsoid apex and base rounded. Rind is medium thick smooth and finely pitted. Skin golden yellow changing to orange red at full maturity. Flesh colour is yellow segments are 9–12 juice medium and sweet with good flavour central core is small. The fruit contain 8–16 seeds. It ripens in the month of November. It is a mid-season variety. The tree grows upright foliage is dense cold resistant but it has alternate bearing habit.

Shamouti
This orange is the famous one for its seedless character. The origin place is Palestine. It is a mid-season variety and extensively grown in Palestine. It is believed to be a bud sport or bud mutant from the Bellady orange of Palestine. The fruit is ellipsoidal in shape medium to large sized. Rind thick firm surface finely pitted but relatively smooth. Pulp colour is light orange juice medium sweet in taste with rich in flavour.

Valencia Late
The place of origin is probably in China. The fruit is medium to large sized round to slightly oval in shape. The colour is golden yellow when mature. Rind is thin smooth tough axis medium solid or semisolid sections 9–12. Pulp is orange in colour juice content is more sweet with excellent flavour. The fruit contains 5–6 seeds. It is a late maturing variety. It is cultivated in Punjab.

Hamlin
The place of origin is in Florida and named after the owner of the orange grove in which it was found in 1879 and developed as a chance seedling. Fruit medium orange red apex rounded and slightly scarred rind smooth thin bright segments 11–12 uneven in size. Pulp juicy with excellent flavour. The fruit contains 1–5 seeds sometimes fruits are seedless.

It is grown on large scale in Florida. In India Hamlin oranges are grown in Punjab, Haryana, Uttar Pradesh. This is an early variety. This variety is reported to be more winter hardy than most sweet oranges.

Batavian
This variety has come from Batavia. Rind is tight yellowish green with pale yellow patches on the green rind. The axis is hollow. This is mainly grown in Coastal districts of Andhra Pradesh.

Propagation
Sweet orange is commercially propagated by budding. Percentage of polyembryony varies from 40 to 95 per cent.

Raising of Seedlings for Rootstock
The seeds are extracted from fruits of the desired trees. They are treated with fungicides and then sown in well prepared primary nursery. Under good conditions seeds germinate in 20–25 days. When seedlings attain 4–6 leaf stage are transplanted in the secondary nursery beds. While transplanting seedlings in the secondary nursery all type sexual seedlings should be discarded leaving uniform upright and vigorous seedlings which are true to type nuclear seedlings. The planting or seedlings in the second nursery is done at 20–30 cm distance both ways.

Budding
It sweet orange budding techniques like patch forkert or T budding may be followed. The best time of budding is when the plant has good sap flow and the cambium tissue is highly active. Well swollen unsprouted buds from about one year old non-angular branches are preferred. Budding should preferably be done at a height of about 20–25 cm from the ground level. The bud graft or buddlings become ready for
Planting in 6–9 months after budding.

**Planting**

It is desirable to dig the pits well in advance to planting of sweet orange buddings or bud grafts. The pits are dug 60 cm³ size in deep soil and 75 to 100 cm³ in shallow soil. The pits are filled up with 20–30 kg well rotten farmyard manure and good soil. The distance of planting may be 4 × 4 m or 5 × 5 m. Yield per hectare is increased with closer planting distance. A greater percentage of fruits is found in the upper parts of the trees planted at closer spacing whereas it is more inside in wider spaced trees. Planting is done in the beginning of monsoon where rainfall is light. Whereas in areas of heavy rainfall it is done at the end of monsoon. Planting in spring is not advisable because spring planted plants have to pass through the ensuing summer. Further plants will require irrigation at frequent intervals and protection from the hot and desiccating winds and high temperatures during the summer.

In North India manuring is done in winter (December–January) with a second dose of ammonium sulphate applied in April–May after the fruit set. In Western and Southern parts of India manuring is done before the onset of monsoon. Sometimes the second application is also given in December or early January.

Besides application of micronutrients (Zinc, boron, and iron) in the form of foliar feed or soil application improves the general health of the growing trees and results in improving the yield. Micronutrients help in controlling citrus decline. The chlorotic condition of citrus leaves has been reported to be due to low availability of micro nutrients which are especially more acute in calcareous soils.

Zn deficiency in sweet orange causes chlorosis in leaves. It is believed that Zn deficiency is caused by antagonistic effect of Fe on Zn availability. The critical level of Zn in citrus leaves for clear distinction between healthy and chlorotic plants appeared to be 20 ppm. Generally the healthy green leaves had lower concentrations of P and Fe and higher levels of N, Ca, Mg and Mn than chlorotic ones. The concentrations of K, S, and Cu are more or less in the same range in both cases. Soil samples supporting chlorotic plants had in general a low content of available Zn and a high level of available Fe. Visual symptoms of Zn deficiency can be corrected with the soil application of 500 g ZnSO4 per plant in cv. Blood Red Malta.

Alternate bearing (that has also been recorded in oranges) has been noted in Washington Navel oranges on sour orange rootstock. In the Off year leaf micronutrient contents (especially Zn and Mn) have been low but NPK contents have been higher. The opposite occurred in the On year. Foliar application of chelated Mn, Zn and Fe has been found to increase a level near that of control trees in the On year. It suggests that the balanced micronutrients application could help in reducing biennial bearing.

**Irrigation**

Just after planting and also after application of fertilizers irrigation is given. Subsequent irrigations depend on climatic conditions and soil types. During the month of July to October when rains are expected watering is done only where there is long spell of drought. During summers irrigations at short interval of 7 days are needed. However during winter the interval of irrigation extends to 12–15 days. Heavy soils require irrigation at wider intervals than light soils. Check basin system is usually followed. Care is taken that the irrigation water dose not touch the tree trunk directly and a dry area needs to be maintained near the tree trunk. This can be maintained by providing mound of earth around the tree trunk well below the bud union.

Flowering and fruiting periods are critical where irrigation should essentially be done. Non availability of sufficient soil moisture during these stages will result in drop of flowers and newly set fruits. The third critical period is maturity period of fruits. During this period water shortage results in shrinkage of the fruit and drying of pulp and very poor fruit juice.
Interculture and Intercropping

Shallow cultivation at 3–4 months interval keep down the weeds, provide soil aeration, help in conserving soil moisture, etc. Deep cultivation at frequent interval will damage root system, it depletes the soil organic matter, spoils the soil structure, creates plough sole and reduces water holding capacity of the soil, increases soil erosion, it is believed that it induces decline.

Sweet orange plantation can be intercropped with leguminous crops like berseem (Trigonella alexandrium) lucerne and Phaseolus trilobus without any adverse effects on the yield and fruit quality. The other common leguminous crops are sunhemp (Crotalaria jonccea), cowpea (Vigna unguculata), dhaincha (Sesbania aculeata), senji (Melilotus parviflora), vegetable crops like Tinda, Kadhu, Guar (Cyamopsis tetragonoloba).

Training and Pruning

Young plants should be given support if needed so that they do not bend. Sprouts arising below bud union and water sprouts should be removed as and when they are seen on the plant.

Sweet orange tree does not require pruning except unwanted (The branches touching the ground) diseased twigs are cut and removed out of the field. Sometimes more twigs are required to be removed off from the trees grown at high plant density programme.

Bahar Treatment

Under western and southern parts of India, climate is mild, therefore, sweet orange trees do not go in rest. In fact, resting is essential for high production. Under mild climatic areas, growers like to have Mrigbahar crop because this helps them to tide over the water scarcity in the months of April and May. It is done by withholding water 60 days in advance of the normal flowering season. And about 30 days prior to commencement of flowering season roots are exposed by removing soil around the tree trunk. The depth of soil removal is about 10–15 cm or so. After about 6–10 days of exposure soil is back filled along with 20–25 kg of farmyard manure followed by light irrigation and which is followed by heavy irrigation for 4–5 days. In about 10–12 days there is profuse emergence of new flush of leaves and flowers. This treatment cannot be followed properly in the areas where rains are expected irregularly, especially in South India. Also, this treatment cannot be followed in North Indian climate where summer and winter seasons are quite distinct in these areas the trees flower normally once in a year in the spring season (February–March). Root exposure always is not recommended.

Fruit Drop

In sweet orange, pre-harvest fruit drop is a common problem. The percentage fruit drop varies with different cultivars. Mosambi and Malta Blood Red are more prone to pre-harvest fruit drop than Valencia Late. The fruit drop may be due to mainly two reasons (i) physiological fruit drop and (ii) pathological fruit drop.

Physiological fruit drop

In this type of fruit drop, the dropped fruits look sound and normal and have no apparent signs of any incidence of insect pest or disease. The following causes may be attributed (i) Formation of abscission layer at the stem point. (ii) Imbalance of growth regulators such as auxins, cytokinins, gibberellins, etc. (iii) Excess or deficiency of certain essential nutrients. (iv) Unfavourable weather conditions. (v) Faulty cultural practices.

Mandarin

The mandarin group includes all types of loose jacket oranges commonly called by the Indian name Santra such as the Nagpuri Santra, Coorg santra, the Khasi orange, and the Desi type. At present mandarins are commercially grown in India. The tree is small, spiny with a dense top. The leaves are long, lanceolate
petiole slightly margined  articulated  flower white  solitary  perfect. The size of fruit is yellow  reddish orange. The core is hollow. The rind is thin  rind and segments are easily separated. The number of segments is 10 14. The pulp quality is exceptionally fine. The seeds are small beaked  cotyledons green highly polyembryonic  but wide range (10 100%) of it  is reported.

Uses
The fruits are used as table purposes. The juice is excellent for drinking purpose.

Climate
Mandarins require subtropical and tropical climate. They grow well in submontane tracts with elevation from 600  1100m  and rainfall ranging from 75  250 cm.

Soil
Mandarins grow on a wide range of soils but for getting higher yields and having long productive life span of plantation  soils which are medium to light loam  deep  well drained  free from excess salts and having adequate content of organic matter are most suitable. High content of organic matter in the soil is necessary for the effective combination of mycelia and mandarin root as they lack root hairs. The soil pH ranges from 5.5 to 8.0  is suitable for mandarins.

Varieties

Nagpur Santra
This is one of the finest mandarins grown in the world. The origin place is India and occupies the premier position. The tree is large  vigorous  moderately spreading  spineless with compact foliage. It is a prolific bearer. The fruits are medium in size  sub  globose in shape. The colour is not uniform but generally cadmium. Surface of the fruit is smooth and glossy. The base (stalk  end) is slightly drawn out and warty with glandular furrows. The rind is thin  separated very easily. The number of segments is 10 11. The amount of rag is little. Juice content is abundant  yellow in colour with excellent flavour  sweet in taste. The number of seeds per fruit is 6  7. The maturity period is generally January  February.

Khasi Orange (Mandarin)
It is commercially grown in Assam. The tree is generally medium to tall with an erect habit  dense foliage both thorny and thornless. It is a prolific bearer. Fruits are depressed  globose to oblate in shape. Colour of mature fruit is orange yellow to bright orange. The surface of the fruit is smooth  glossy. The base (stalk end) is even or obtuse  occasionally short necked  slightly ribbed. The rind is thin and is separated very easily. The number of segments 8 10  rag little to medium. The pulp vesicles uniformly orange  coloured coarse  very melting  flavour aggreable  juice abundant  orange coloured. Sweetness and acidity well blended. The seeds very from 9 to 25 per fruit.

Coorg Orange
It is the most important commercial variety in South India. It is propagated by seed. The tree is large vigorous upright growth compact foliage  sparingly spinous. The fruits are oblate to globose in shape. The colour of fruit is bright orange yellow. The base necked or depressed with glandular ribs extending through the collar. The rind is thin and  soft  slight adherence  easily separated. The number of segments is 9 11 rag is little. Juice is abundant  deep chrome in colour. The number of seeds varies from 14  30 per fruit.

Desi Mandarin (Pathankot)
This variety of mandarin is mainly grown in the Punjab hills. The tree of this variety is large  with semi upright growth habit having compact foliage. It is spinless. The fruit is ovoid to subglobose. Surface pitted semi  glossy and finely wrinkled. The base of the fruit is shortly necked and furrowed  rind adherence is
slight. The number of segments is 7–10. Juice abundant, deep chrome colour; the number of seeds per fruit varies from 3–7.

**Kinnow Mandarin**

Kinnow mandarin is a hybrid between King (Citrus nobilis Lour as parent) and Willowleaf (Citrus deliciosa Tenore as parent) mandarins developed by Dr. H.B. Frost at Citrus Experiment Station, California (USA) in 1915. It was first introduced in the form of virus free budwood and raised on Jatti Khatti (Citrus jambheri) rootstock in 1959 at the PAU Regional Research Station, Abohar from the University of California. It is cultivated in the Punjab, Haryana, lower hills and velly areas of Himachal Pradesh, Uttar Pradesh, Karnataka (Coorg, Hassan and Chikmangalore district), Kerala (Wynaad and Palghat district), Tamil Nadu (Ootacamund and Madurai districts). In north India, the cultivation of mandarins is limited due to the acidity and puffiness of the fruit. Kinnow has been proved promising in place of mandarins because kinnow has wide adaptability to variable agro-climatic conditions and also comparatively more resistant to insect pests and diseases. Incidence of fruit drop due to hail storms or other reasons is also comparatively less. Kinnow is usually less prone to bird damage as almost two-thirds of the fruits are known to bear in the interior of the tree.

Kinnow mandarin grows vigorously. Trees possess dense foliage and lush green in appearance. Kinnow fruit is medium in size and is globose to oblate in shape. The apex is flattened. The number of segments is 9–10. The axis is semi-hallow. The colour of fruit is attractive shining deep orange at ripening. The peel is thin, glossy and also adherent but can be peeled off easily by hand. Juice is abundant (50%) having good contents of TSS (15%) and sugar (11%) with good flavour. Seeds vary from 14–19 in number and are polyembryony.

**Climate**

Kinnow can be grown under variable agro-climatic conditions. It can tolerate even frost if it occurs for only a couple of days. The submountainal climate produces fruits of high quality.

**Soil**

Kinnow thrives well on deep fertile, sandy loam soils having pH ranged of 6.5 to 7.5. It is not advisable to establish kinnow orchard on soils which are saline, alkaline or having a lime concretion layer in the lower horizons.

**Propagation**

Kinnow is highly polyembryonic (75%) and thus seedlings also come true to type after removal of sexual seedlings at nursery stages. But to raise plant further hardy, it becomes necessary to propagate them on hardy rootstock like karna khatta (Citrus karna Raf.) and Jambheri (Citrus jambheri). The method of budding, time etc. are similar to mandarins.

**Planting**

The pits are due at the distance of 5.5×5.5 m with dimensions of 60–75 cm and they are filled with a soil mixture consisting of one part FTM or compost and three parts top soil. The pits are left as such so that soil settles well in the pits. Planting is done in the centre of the pit. While planting care is taken to avoid burying of bud union portion in the soil. The best time of planting is in the months of August–September.

**Manures and Fertilizers**

A bearing kinnow tree may need application of 80–100 kg of FYM, 400–600 g of nitrogen, 200–300 g of phosphorus and 400 g of potassium for good growth and production. The total amount of phosphorus and potassium and half amount of nitrogen are applied during February–March and the remaining half of
nitrogen during September–October. Application of urea at one per cent zinc and manganese at 0.5 per cent as zinc sulphate and manganese sulphate respectively during the main flushes is beneficial to overcome the zinc and manganese deficiencies which are very common.

Irrigation
Kinnow plantation requires very light and frequent irrigation. During summer irrigation is given at an interval of 8 to 10 days. During winter it is done at 20–25 days intervals. Generally irrigation is not needed during rains except where there is a long break.

Interculture and Intercropping
Young plants of kinnow require hoeing twice or thrice in year to keep down the weeds and to provide good conditions for growth. Bearing orchards are ploughed and harrowed after monsoon is over for proper cleaning.

Kinnow trees attain yield stabilization by the age of 12–15 years. By 8–10th year the trees start yielding good profit. It is better to discontinue intercropping by 7th or 8th year. Suitable intercrops are: Moong, urd pea, cowpea, cabbage, okra and potato.

Flowering and Fruiting
Kinnow plants start bearing flowers and fruits 4–5 years after planting. It has precocious bearing and very high fruit yield during early years of its life. Because of so heavily bearing the tree get hausted leading to collapse or gradual decline. Among other factors the malnutrition seems to be the major cause for declining of bearing trees. Not only this kinnow trees show tendency of irregular bearing. That is heavy crop year is followed by poor crop year with small fruits of poor quality. The alternate bearing tendency of kinnow plantation can be improved up to certain extent with the help of growth regulators. Among them NAA at higher concentration has been found to act good fruit thinner and there by reducing the crop load in heavy crop year. NAA is also easily available and convenient in use. Application of NAA 350 ppm 30 days after full bloom induces reasonably amount of fruit thinning and help in regulation of the crop in the subsequent year. Another effective method of hand thinning but it cannot be followed on large scale except with kinnow trees growing in backyard.

Harvesting
Being non-climacteric kinnow fruits fail to ripen after harvesting and do not improve in taste after harvest unlike many other climacteric fruits like mango, peach and banana. Therefore kinnow fruits should be harvested only when they are fully ripe, attractive orange coloured and acceptable sugar–acid blend. The best time of picking Kinnow in north India is from end of January till the first fortnight of February. In earlier picked fruits acidity is higher and fruit is sour in taste. The fruit should be harvested with a clipper retaining a short twig button end along with the fruit. Pulling the fruit from the branch ruptures the skin near the stem end leading to fungal infection and subsequent rotting of the fruit. The fruits should not be harvested during or immediately after rain or when they are covered with dew because by absorption of water the peel becomes soft and turgid and is bruised during handling.

Yield
Well grown up kinnow tree of about 10–12 years age bears about 2000 to 5000 fruits. However yield potential of tree depends on climatic conditions, soil types, freeness of pests and disease and management practices.

Sour Lime
Sour lime (Kagzi lime, Acid lime, Mexican lime) in Hindi is known as Neebu. It is a profusely branched
thorny shrub or small tree. The leaves are small with narrowly winged petioles. The flowers are small pure white and are borne in clusters. The fruits are more or less round or oval smooth having thin rind (papery) attached lightly. The immature fruits are dark green in colour which changes to light yellow when ripe. The colour of the pulp is light greenish yellow taste is acid aromatic cells fine and shiny. The number of segments is 9–11. The number of seeds per fruit is 9–10.

Sour lime is found in most parts of the tropics. In India it is cultivated in Tamil Nadu Maharashtra West Bengal Punjab Madhya Pradesh Andhra Pradesh Delhi Uttar Pradesh Karnataka Gujarat. It is cultivated in the plains and up to 1200 m elevation. The small fruited lime is the variety grown all over India. A large number of types differing in size shape and colour of the fruits are cultivated. Some thornless types are known but they are not grown commercially. Bearss or Sersian is very important type in Florida: produces fruits larger than the conventional lime totally seedless smaller and less thorny tree easier to harvest.

Climate
Sour lime requires tropical climate. It is tender to frost. Strong winds are harmful. In the more humid areas of Assam and West Bengal where the rainfall is above 125 cm the lime becomes highly susceptible to citrus canker which makes the trees unproductive and short lived. Sour lime may not be cultivated in the area where the temperatures occasionally fall below the freezing point. Sour lime is successfully cultivated in west and south India where winters are free from frost and the annual rainfall does not exceed an average of 75 cm. Sour lime can successfully be grown from sea level to 1000 m or so elevation.

Soil
For the plantation of sour lime soil should be at least 1.5 m deep. It should be well drained. Heavy soils should be avoided for planting. A high water table of a permanent or fluctuating nature is unsuited and low lying localities which are subjected to water stagnation should always be avoided.

Types/Varieties of Lime

Kagzi Lime
It is the best variety grown all over the country. It has two types of fruit round and oval.

Chakradhar Lime
This variety of lime was derived cv Kagzi. It has round fruit with thin papery rind and a 60–66 per cent juice content. It is a thornless and seedless selection. It has a greater yield and vitamin C (ascorbic acid) 118.2–140.8 mg/100g and acid content (8.3–9.1%) than Kagzi. Trees of Chakradhar begin bearing in their 4th year and are compact and semi spreading.

Rangpur Lime (Citrus limonia Osbeck)
Rangpur lime is indigenous to India. It is fairly tolerant to frost. It is commonly grown for rootstock purposes because it is more hardy than true lime. However it is susceptible to citrus scab. The fruits are used for making limeade. In fact it is not true lime. The fruit has loose rind and segments are easily separated. The pulp is light orange yellow in colour. The seeds are small cotyledons green polyembryonic.

Taheti (Persian) Lime (C. latifolia Tanaka)
It is a native of south pacific. It is a triploid and produces no viable pollen. It might be a hybrid between lime and lemon or even a distinct species.

Propagation
Sour lime is mainly propagated by seed. Propagation by seeds is followed due to polyembryonic nature of it. In sour lime about 78 per cent seeds possess polyembryos. Each polyembryonic seed produces three to four seedlings. Among them one is sexual origin and remaining are nucellar. Nucellar or apogamic
seelings breed true to type. Besides vegetative methods like budding layering and stem cuttings are also adopted but only on small scale.

In Punjab sour lime is usually propagated by ground layering. The healthy flexible branches which are close to ground are selected in the month of February March. The selected shoot is notched or a ring of bark is removed in order to encourage rooting before burying the shoot in the soil. The portion from which roots are to be emerged should be properly buried in the soil making top portion free for growth. A piece of stone or brick is kept on the portion subjected to layering so that it is kept in position till rooting is over. The soil is always kept moist for encouraging rooting.

Root formation is over by 8 10 weeks. Thereafter the layer is cut from the mother tree and lifted for planting in pots or in the main site.

Raising of Seedlings
Freshly extracted seeds are sown on well prepared nursery bed at the distance of 20 × 10 cm and 1.5 to 2 cm deep. Germination completes within 3 weeks. The sexual seedlings which are usually stunted and poor in growth compared to apogamic or nuclear seedlings are uprooted carefully. Removal of sexual seedlings is essential because they do not breed true to type. The apogamic seedlings are identical to the parent in growth and production. Seedlings are ready for transplanting 6 to 9 months after sowing. However usually one year old seedlings are preferred for transplanting.

Planting
The pits are dig during summer with a dimension of 60 75 cm3. They are filled with a mixture of top soil and well decomposed compost or farmyard manure at the ratio of 50 : 50. The filled pits are left till first shower of monsoon. Planting is done in the centre of the pit with a single healthy seedling or graft. The root zone of transplant is set properly and pressed around it. Planting is followed by irrigation in the absence of rains.

Sour lime is planted at a distance of 5 × 5 or 6 × 6m. Distance can further be reduced to 6 × 5 6 × 4 m if soil is poor. The lime tree declines after certain period of cropping but it is early if they are planted closer. But decline can be prevented by removing alternate row of plants or alternate plant from the row that will provide sufficient growing spaced and will avoid competition for essential requirement like solar radiation water and nutrients. Closer plantation has also been reported to have more incidence of pests and diseases which may lead to decline and reduced production.

The best time of sour lime planting is the onset of monsoon. The survival and establishment of lime plants remain very high during monsoon season. However planting can also be done during September October of February March when assured irrigation facilities are available.

Manure and Fertilizers
Generally about 50 kg of FYM 500 g N 400 g P2O5 and 900 g K2O per plant from fifth year and onwards every year it is applied first in December January before spring flowering and the second application is done in June July. These timings of application can be adjusted according to climatic conditions of the region in which it is grown.

However the following doses of fertilizers (g/tree) and FYM (kg/tree) are applied in different states.

Irrigation
As stated earlier the very first irrigation is done just after planting. Subsequent irrigations are needed during rainy season if rains are regular. During winter lime plants are irrigated 15 20 days intervals whereas during summers at 8 10 days intervals. Sufficient soil moisture is maintained during fruit setting and fruit development.
Interculture and Intercropping
During rainy season weeds become a problem hoeing once or twice will keep down all the weeds. Proper cleaning is done during post monsoon season during (September October). Only shallow cultivation should be done. Much of clean cultivation practices will not be beneficial. Sour lime is a evergreen in nature after harvesting it should be given some rest during the month of October to November in the South and Western India and in the month of December and January in the North India developmental stages which results in high percentage of fruit retention (i.e. low percentage of fruit drop and ultimately high fruit yields). Sour lime tree develop full canopy in 4 to 6 year. Intercrops can easily be taken during early stages of crop growth depending upon population density. Usually vegetable crop particularly legume vegetables are grown with advantages.

Training and Pruning
The young plants may be provided with support with bamboo split sticks if needed. Later when new sprouts form near to ground level are removed as and when they are seen. Bearing trees may be pruned for unwanted branches like criss cross branches diseased and dead and branches which are profusely growing on the ground and the water sprouts. Pruning operation provides good framework to the tree which should be attended to yearly.

Flowering and Fruiting
Sour lime starts bearing flowers and fruits from the fourth year onwards after planting. Under natural conditions the trees flower all the year round each flush bringing forth new blossom. The fruits mature in six months after flowering. In Gujarat about 60 per cent of the total crop is harvested during July to September 30 per cent from October to January and 10 per cent from February to May. In north India the main harvesting season is in the months of August September. Higher fruit setting minimum fruit drop and higher fruit yield of sour lime are obtained with the spraying os ZnSO4 at 0.6 per cent + 2 4 D at 20 ppm in early January for the spring flush and in early May for the summer flush followed by GA3 at 50 ppm + ZnSO4 at 0.6 per cent.

Sweet Lime
Sweet lime (Mitha neebco) has non acid juice unlike sour or acid limes. It bears very profusely. Its fruits are seen in the markets much before the arrival of oranges. The sweet lime is a large and spreading tree with medium size leaves characteristically somewhat rolled and cupped pale green in colour with prominent oil glands and naked to margined petioles. The flowers are large and pure white. The fruit is globose or ovoid generally with low flat papilla. The rind is tight smooth thin and light green but lemon yellow on full maturity. The sections in the fruit are closely set. The colour of flesh is yellowish white. The content of juice is abundant taste is sweet insipid devoid of acidity. The number of seeds per fruit varies from none to five. The fruit shape foliage characters light coloured inner seed coat an chalazal spot are very distinctive characters light coloured inner seed coat an chalazal spot are very distinctive characters. Polyembryonic characters of sweet lime suggest that it is probably hybrid that is nearly sterile. The possibility of hybrid between Mexican lime and sweet citron was reported and therefore sweet lime was placed provisionally under limes.
In India sweet lime is commercially grown in Punjab Tamil Nadu and Assam. It is also grown on small scale in other parts of India. Infact its cultivation is limited to home gardens.

Climate
The sweet lime can be grown under a wide range of climatic conditions. It is more hardy in nature than
Kagzi lime. It is tender to frost but can withstand frost conditions better than Kagzi lime. It can also grow under dry conditions. It also grows successfully at higher altitudes in Assam.

Soil
The sweet lime can be grown on a variety of soils. However, ideal soils are well drained deep loams.

Varieties
Mitha Chikna
The plant is medium tall, spreading, densely orange and thorny. It is a prolific bearer. The fruit is almost spherical or globose, light yellow, surface very smooth and glossy. Rind is very thin, leathery, adherence medium to strong. The number of segments is 10 to 11. The pulp vesicles uniformly white. Juice is abundant, taste sweet or insipid sweet, flavour agreeable. The rind is medium. The number of seeds per fruit is one to five. Seeds are white in colour and chalazal spot are light yellow.

The other variety is large fruited (the fruit look like grape fruit). The colour of fruit is lemon yellow, apex slightly depressed, base slightly necked, the ring is rough and thick and oil glands are prominent. The flesh colour is yellowish white. Juice is abundant, nice taste, flavour agreeable and rather better than that of the mitha chikna variety.

Propagation
Sweet lime is commercially propagated by hardwood stem cuttings. However, it can also be propagated by budding, air layering, and occasionally by nucellar seedlings. Sweet lime is highly polyembryony; the average number of embryos per seed has been reported as 5.8.

The hardwood cuttings are prepared from selected shoots of consistently high yielding trees. The cuttings are best rooted during the monsoon season under open conditions. The root formation in cuttings can be enhanced by the application of IBA at 3000 ppm by quick method. Under favourable conditions rooting completes in 4 to 6 weeks. However, the plants raised from stem cuttings are generally shallow rooted and are surface feeders, which is a demerit.

Air layering is also done successfully in the commencement of rain. In about four months time, the layer is ready for separation.

Propagation by shield budding is successful provided that the operation is performed in March April and only the current seasons (immature) bud wood is used. The suitable rootstock is jatti khatti (rough lemon) in the Punjab, Soh myndong (rough lemon) in Assam, Karna Khatta in Uttar Pradesh and Jambheri in other parts of the country.

Planting
The pits are dug at the distance of 6 x 6 m with the usual dimension of 100 cm3 to 75 cm3 depending upon the soil and climatic conditions. They are filled with top soil or silt mixed with well rotten farmyard manure. Thereafter, they are watered copiously and left for a few days to allow the contents of the pits to settle down.

Usually, sweet lime is planted in the onset of monsoon in the areas where monsoon are light. However, it is planted in September that is post monsoon season or during the period when rains are light and occasional.

Lemon
The lemon (Bara nibu) has its ancestral form, the galgal which is also in cultivation. The word lemon is derived from the Arabic word Linum means for lemon. In India, it is cultivated in Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Assam and the Punjab. In the north, the lemon fruits are available from December to February when the Kagzi lime is either not available or is rather
scare. The lemon trees are relatively free from diseases like die back wither tip and canker to which the sour lime is very susceptible.

Lemon is a straggling bush or a small tree with thorny branches. The leaves are slightly ribbed and have a distinct joint at the beginning of the blade. The petiole is wingless or very slightly winged. Flowers are purple in colour. Fruits are obovate to elliptical or oblong in shape. The areolar area protruding as a pointed nipple. The rind is thick and lemon yellow in colour. The surface of the rind is slightly rugose. The pulp is acidic in taste and pale yellow in colour.

**Climate**
Lemon requires sub tropical climate. It flourishes under semiarid conditions. It can tolerate frost better than Kagzi lime. It is grown up to 1200 m elevation it yields prolific crops both under irrigated and rainfed conditions. Lemons are more hardy than Kagzi lime.

**Soil**
Lemon is adaptable to a variety to soils. However, it requires well drained shallow soils to a depth of not less than one metre. The area on which lemon is planted should be protected from strong winds by means of suitable windbreaks.

**Varieties**

**Eureka**
This variety was introduced from America and Europe and best suited in the Punjab and Western parts of Uttar Pradesh. Tree medium to large spreading open sparingly spinous. The leaves are large size dark green margin markedly crenate apex blunt pointed or rounded. The fruit is medium in size and obovate to elliptical or oblong in shape. The rind is medium thin colour lemon yellow surface slightly rugose pitted usually with inconspicuous longitudinal ridges. The apex of the fruit is abruptly rounded and areolar area protruded into a slight or prominent nipple. The fruit axis is small and semi hollow to solid. The number of segments is 9 to 14. The pulp tender fine grained pale greenish vesicles slender and conical to spindle shaped. The content of juice is abundant very acid and flavour is excellent. The fruit contains at few seeds none to 6 or more per fruit. The juice has TSS of 8 per cent and acidity 5.47 per cent.

**Lisbon Lemon**
The tree of this variety is large spreading open rather thorny. This is another introduced variety. The fruit is medium in size. The shape is oblong to ellipsoid. The rind is medium thin colour lemon yellow to lemon chrome surface smooth or rugose pitted inconspicuous ribbed. The base of fruit is rounded to slightly protruding. The apex of the fruit is prominently nipped. The axis of the fruit is small and solid to semi hollow. The number of segments is 9 to 11 sometimes seven. The pulp is fine grained cream coloured vesicles conical to spindle shaped slender. The content of juice is abundant very acidic excellent quality. The fruit contains none to ten or more seeds. The juice having about 8 per cent TSS and 5.92 per cent acidity.

**Villafranca**
It was introduced into Florida from Europe about 1875 and is grown on large scale in Florida. The tree is large vigorous with dense foliage. Twigs are thorny. The leaves dark green large broadly lanceolate. Fruit ovaloblong medium to large sized. The colour of fruit at full maturity is lemon yellow. The apex of fruit is pointed blunt base rounded. The rind is smooth and thin. The number of segments is 10 12. The seeds are about 25 30 per fruit.
Lucknow Seedless
The tree of this variety is medium in height. The branches are drooping and thorny foliage dense and light green. Leaf petiole is marginally winged. Fruit is oblong in shape lemon yellow in colour. The rind is smooth and thin. The fruit apex is nipped and the base rounded. The axis is hollow. The number of segments is 9 13. Juice is abundant. Seeds are usually absent. The main season for availability of fruits is during November to January.

Nepali Oblong
Tree small to medium sized crown irregular foliage dense. The leaves are broad and elliptical. Fruit is oblong to obovate in shape. The colour of the fruit is lemon yellow the apex is nipped and the base rounded. The rind is medium thick. The axis is hollow. The number of segments is 11 13. The seeds are very few or absent. The main season for availability of fruits is December January.

Baramasi
Tree medium and vigorous spreading shoots numerous foliage light green dense leaves medium in size broadly lanceolate fruit colour lemon yellow surface smooth shape oblong size small base short but inconspicuous apex gradually rounded rind thin segments 8 10 pulp fine grained pale greenish yellow juice abundant clear very acidic quality excellent seeds 4 14 per fruit.

Kagzi Kalam
Tree medium hardy and vigorous spreading foliage light green dense elliptical to oblong margin crenate apex obtuse acute petiole winged. Fruit medium sized oblong yellow apex slightly nipped rounded base rind thin axis hollow segment 9 12. Pulp light yellow juicy flavour good and sour. The number of seeds per fruit varies from 8 19.

Hill Lemon. (Galgal) C. pseudolemon Tanaka
Galgal is indigenous to northern India. Commonly grown in sub Himalayan regions. The tree tall hardy vigorous and uprightly growing. Foliage is dense and twigs have thorn. The leaves are broadly elliptical with long marginal winged petiole. The fruit is ovate oblong apex slightly nipped base rounded to slightly nipped. The rind is medium thick. The axis is hollow. The number of segments is 8 10. The number of seeds per fruit is about 25 60. The fruit ripens from October to December. Propagation by stem cuttings is successful.
Hill lemons are mainly used for making pickles squashes and candy.

Meyer Lemon
It was introduced into the United States from China in 1908. The tree is semi dwarf thornless resistant to cold. The leaves are small. The fruit is obovate to elliptical or oblong. The colour of fruit is light orange. The rind is thin surface is smooth. The apex round and base is also round sometimes slightly necked and radially furrowed and lobed. The number of segments is 10. The number of seeds is 8 12. It gives fruits throughout the year with main season from November to January.

Pat Lemon
It is an indigenous lemon variety of Assam where it is called Assam lemon. It is also found growing south India and South Maharashtra. Where it is known as Pal Nimboo. It is a chance selection from a variety of lemon known as China Kaghi in Assam. It is grown under the name of Seville lemon in Andhra Pradesh. The variety is tolerant to scab canker and gummosis.
The tree of Pat lemon is small straggling open rather spinous. The fruit is ovoid oblong medium. The colour is citron yellow surface smooth to finely rugose base rounded to short necked apex obtusely
nipped axis medium and semi hollow to hollow. The number of segments is 9 to 12. Pulp is greenish white vesicles slender conical to spindle shaped. The seeds none to several in a fruit. The total solids are six per cent and acidity 5.6 per cent.

**Italian Lemon**
This has been found to grow well in southern states. It can be grown under high rainfall areas. The fruits are large oval with a prominent nipple. This variety is almost seedless.

**Rajamundary Lemon**
This variety has been found to grow in certain parts of Andhra Pradesh. Yield potential is high.

**European Lemon**
This variety is found growing in the north. It is very resistant to frost injury and the citrus canker disease. The fruit is almost of the size of galgal. This is a high yielding type.

**Ponderosa Lemon or Japanese Lemon**
It is truly a baramasia lemon. The tree continues to flower throughout the year and as such fruits of all sizes and stages of maturity can be seen on the tree any time. The tree does not take much growth. It is suitable to grow in home gardens but not suitable for commercial growing.

**Malta Lemon**
The tree is dwarf bushy and compact. The size of fruit is small to medium. Juice is abundant. The seeds are numerous. Malta lemon is found growing in the southern states. Trees of this variety start bearing in the second year of their planting in the sandy tracts of the west coast.

**Propagation**
Lemon is mainly propagated by seeds. The seeds are extracted from healthy fruits. Freshly extracted seeds are mixed with ash and dried in the shade. It is advisable to sow the seeds soon after extraction within three days otherwise viability of the seeds is reduced. Propagation of lemon by seed is not preferred nor it is advisable to follow due to variabilities.

Lemon may be propagated by budding layering marcotting and stem cuttings. Among them budding is preferred as resultant trees raised from budgraft are precocious produce more uniform crop and root and trunk diseases can be avoided by using suitable rootstock. Commonly adaptable rootstock are jati Khatti (Citrus jambheri) and Karna Khatta (Citrus Karna).

**Planting**
For planting of lemon the pits are dug well in advance to planting operation. They are dug at the size of 60 75 cm³ or so depending upon cultivar type of soil and topography of the land. The pits are filled with a mixture of top soil and 10 15 kg of well rotten farmyard manure or compost.

The pits are dug at the distance of 6 × 6 m. Italian limes are planted at a distance of 8 × 8 m because they put on more growth and develop into large canopy.

The time of planting lemons is in the onset of monsoon. However lemon can also be transplanted in the month of September October or February March if assured irrigation facilities are available. Planting is followed by staking and or light irrigation for better survival and establishment of lemon seedlings/grafts and putting on further growth.

**Irrigation**
Just after transplanting light irrigation is given. Subsequent irrigations are given as per need of the crop. During the hot summer months irrigation should be given at 8 10 days interval whereas 10 15 days or so during winter. Adequate soil moisture should be maintained during flowering and fruiting stages.
Manure and Fertilizers
Lemon responds well to manure and fertilizer application. The doses of fertilizers vary with the climatic condition, soil type, and age of the tree. The below are the doses of manure (kg/tree) and fertilizers (g/tree) being applied in states like Andhra Pradesh, Arunachal Pradesh, Assam, Karnataka, and Rajasthan. Generally fertilizers are applied thrice in a year i.e., in December, January, June, July, and September-October. Farmyard manure is applied in June, July, or September-October.

Grapefruit
The grapefruit has its well-known ancestor the shaddock or pummelo (C. grandis). It has separated from pummelo in 1830 by James Macfadyen and assigned as species status (C. paradisi). The grapefruit is cultivated in all the subtropical regions of the world. The name of grapefruit has been given to this type because its fruits are borne in clusters much like grapes. It is cultivated in the USA, Palestine, South Africa, Brazil, West Indies, Australia, and New Zealand. In India, it is cultivated in the Punjab, Western parts of Uttar Pradesh, around Pune in Maharashtra, and Deccan Plateau. Grapefruit can be safely cultivated in Rajasthan, parts of Madhya Pradesh, and South Saurashtra where irrigation is available. The grapefruit is a large, round-topped tree with a dense foliage. Twigs are angular when young, leaves are larger than those of the sweet orange but smaller than those of pummelo. The petiole is broadly winged, but comparatively less than those of the pummelo. The flowers are large in size, they are borne singly or in small clusters in the axis of leaves. The size of fruit is larger than that of sweet orange but smaller than the pummelo. The shape of fruit is globose or pear-shaped having white or pink flesh. Juice content is abundant and it is mildly bitter. The seeds of grapefruit are smooth as compared to the ridged ones in pummelo, white and polyembryonic.

The grapefruit contains considerable quantities of Vitamin C and fair quantities of Vitamins A and B. It also contains minerals such as calcium, iron, and phosphorus. The grapefruit juice particularly aids digestion and increases appetite. It produces an alkaline reaction in the stomach. The cellulose in the pulp of the grapefruit and the acid in the juice are laxative in effect and thus, they aid in keeping the digestive tract always clean and healthy. The grapefruit juice is low in calories. It has been found to be a good solvent of surplus body fat and therefore useful in combating obesity. The bitter glucoside, Naringin, prevents against malaria. The grapefruit juice is beneficial in preventing enterites, dysentery, and diarrhoea. Juice has also been found helpful in preventing and curing diseases such as acidosis, anaemia, chlorosis, scurvy, beriberi, and rickets.

Climate
Grapefruit thrives in the dry and arid plains where the summer temperatures rise to 115°F, the winter temperatures occasionally go below freezing point, and the rainfall ranges from 15 to 150 cm during the southwest monsoon. Young plants may be damaged by frost and, therefore, have to be produced by a thatch of grass. The grapefruit can be grown up to 500 to 1000m or so altitudes a higher rainfall and a higher atmospheric humidity are detrimental to its growth and encourage the spread of citrus canker which kills young growth and disfigures the fruits.

Soil
For successful cultivation of grapefruit, well-drained, deep, and free-working alluvial loam soils are the best. However, this can be grown on medium black soils of Deccan plateau provided that they are at least 1 to 1.5 m deep. Shallow soils are unsuitable because due to the limited soil space, the roots cannot expand and grow properly. Similarly calcareous soils containing large quantities of lime are quite unsuitable.

Varieties
**Marsh Feedless**

It was introduced into India from USA. It is one of the best commercial varieties. It is high yielding. It is nearly seedless. The fruit is medium to large size. The shape of fruit is ovoid globose to oblate. The colour when ripe is light yellow. The surface of rind is smooth and glossy. Thickness of rind medium leathery and moderate adherence. The pulp is colonial buff fine and tender. Number of segments vary from 11 to 14 axis mainly solid but sometimes semi hollow. Juice is abundant with excellent flavour. Only a few seeds are found which are large sized white when cut. The juice having TSS about 9 per cent and acidity 1.5 per cent.

The fruits of this variety can be held longer on the trees without any deterioration due to its seedless character. The variety Marsh Seedless belongs to Pallid pulp group of grapefruit.

**Duncan**

Duncan variety of grapefruit originated as a chance seedling in Florida. Duncan variety of the grapefruit is the next best to Marsh Seedless. It bears very heavily under Indian conditions. It is medium to late variety. The fruits are large ovoid globose to oblate and sometimes oblique. The colour of the rind is light yellow (Chrome lemon) the surface is smooth and glossy and the thickness of rind is medium leathery with moderate adherence. The pulp is colonial yellow fine and tender. The segments vary from 11 to 14. The axis is solid to semi hollow. The juice abundant flavour and aroma are very pleasing acidity and bitterness are moderate. The juice having 9.5 TSS and about 1.1 per cent acidity. The fruit contains numerous seeds usually varies from 30 to 60 or so they are medium to large sized white when cut. The variety Duncan belongs to Pallid pulp group.

**Foster**

This variety originated as a bud sport on a Walters grapefruit tree and discovered in 1906 1907 by R.B. Foster and was named after him.

Among pink or red pulp group Foster strain is the best one. It bears prolifically under Indian conditions. The fruits are medium to large ovoid globose to sub globose. The colour of the rind is narcissus flushed with pink (Salmon) surface coarsely pitted and glossy. The rind has medium thickness leathery with moderate adherence. Mesocarp is ivory yellow wity pinkish shade. The pulp is pinkish (Salmon) fine and tender segments are 12 to 16. The axis is semi hollow. The juice is fairly abundant flavour and aroma are pleasant and having medium acidity and bitterness. TSS is 10 per cent and acidity 1.15 per cent. The fruit contains numerous seeds (30 to 60 or so) they are medium to large sized white when cut.

**Saharanpur Special**

This variety was developed at Saharanpur Botanical Garden. This is successfully cultivated in Saharanpur and nearby area in Uttar Pradesh and in the Punjab. The fruit shape is round to oblate empire yellow surface smooth base round or slightly depressed apex slightly depressed. The rind is medium thick. The axis is semi solid or slightly hollow. The number of segments is 12 14. The pulp is light yellow and soft vesicles loosely packed juicy flavour fair and sweetish sour. This variety has numerous seeds in its fruit. Fruit ripens from November to February. The variety Saharanpur Special resembles the Marsh Seedless in many characters except number of seeds per fruit.

**Ruby**

It is a budsport from the Thompson grapefruit and found in Texas in 1929. It belongs to pink or red pulp group. It resembles in almost all characters to the cv. Thompson or the Marsh except crimson flush on its smooth rind and has finely textured pulp of ruby hue. The deep red colour is uniformly distributed throughout the pulp. Ruby grapefruit is being planted extensively in Texas.
Thompson (Pink Marsh)
This variety comes under pink fleshed group. It is a bud sport from a typical Marsh tree in Florida. It is very successfully growing in south India. It is an early type and bears well under south Indian climatic and edaphic conditions.

Triumph
This variety is high yielding and prolific bearer but not successfully grown. The main drawback of this variety is to have a tendency for drying juice sacs.

Propagation
The grapefruit is successfully propagated by budding on commercial scale. The Jatti Khatti rootstock (C. jambhiri) has been found to be a very compatible rootstock in the South India. Karna khatta (C. karna) has given outstanding performance in the north India particularly in Uttar Pradesh. In Assam the grapefruit does well on pummelo. However in the Punjab from recent studies it has been clear that the grapefruit cv. Marsh Seedless budded on Carrizo and Troyer (C. trifoliata × C. sinesis Osbeck) produced maximum tree volume girth and the maximum fruit yield and quality compared to the trees budded in Jatti Khat (C. Jambheri) and Karna Khatta (C. karna Raf). The grapefruit is polyembryony and varies from 60 to 95 per cent (6 13 14). Due to its polyembryonic nature seedling trees have been frequently found to be quite satisfactory.

The operating like planting irrigation manuring and inter culture for the grapefruit are just the same as for oranges and lemons.

Planting
As far as possible the grapefruit orchard should be well protected from hot winds during summer especially in northern India. At least one or two year advance to planting of grapefruit a wind break of some quick growing tree like Shisham should be planted on the south western side.

First of all the land is ploughed harrowed and levelled. The plot is demarketed and spots are marked at the distance of 6 × 6 to 8 × 8m. This pits are dug 60 75 cm3 and filled with topsoil mixed with about 10 15 kg of well decomposed farmyard manure 1 kg of bone meal and 2 kg of woodash if available.

The best time of planting of grapefruit is the onset of monsoon in southern India whereas in the north planting is done in the months of January February. The plants are planted in the centre of the pits. While planting the bud joint should be kept well above the ground level.

Irrigation
Just after planting light watering is done for better survival and establishment. Irrigation is done by adopting basin method basins are made to 60 cm radius round the trunk. The size of the basin should be increased from time to time to suit the ever increasing size of the plant. During dry season young plants need watering throughout the year. However irrigation applied from the flowering stage to fruit maturity has been found to be more effective than frequent irrigation throughout the year. A water deficit of 5 cm from field capacity is the optimum level at which the depleted available soil moisture could be replenished effectively. It is too early and too late to irrigate when the soil water deficit reaches 2.5 and 7.5 cm respectively. A single line drip irrigation is economically advantageous because of lower investment in equipment. Tree growth is greatest with sprinkler irrigation which give better distribution of water than the other systems like drip and under tree spray. There is maximum use of water and fertilizer through roots in the top layer of soil (20 cm) and at 120 cm radial distance to the trunk.

Training and Pruning
During early stage of growth plants need support which is given with the help of wooden stick fixed near to
the stem. Any sprout develop below the bud union is removed as and when it is seen. Grapefruit trees require less pruning than orange trees but considerably lesser than lemon trees because of their natural tendency to spread low unlike lemons. Under humid tropical conditions the drooping branches should be pruned to avoid infection by gummosis and foot rot fungi. Due to their more dense foliage and heavier cropping grapefruit trees give out more dead wood than orange trees. Growers should therefore keep this factor in mind while removing the dead wood. The grapefruit should be pruned for the first time to form a foundation framework of the main branches which are well shaped and balanced may be allowed to remain on the trunk the rest may be removed and the stubs cleared with pruning shears. The main branches of the tree should be encouraged to arise on the trunk not less than 30 cm and not more than 75 cm above the bud joint.

For the first five years the trees put out considerable leafy growth. The branches that are more or less obliquely inclined and are fully exposed to the sun are the productive growth arising vertically from high points on the trunk or the main limbs especially in the centre of the tree (called water sprouts) should be promptly removed. The cuts made while removing them should be clean and close to the stem. Water sprouts should always be pruned as and when seen.

### Pummelo

The pummelo is a monoembryonic in nature. The tree grow up to 3 4 m in height. Leaves are large with broadly winged petiole. Lower surface of the leaf is pubescent particularly the main vein. Fruits are mainly borne singly. Fruits are large sized subglobose to pyriform in shape with thick and spongy rind. Fruits are sweet and moderately juicy. Seeds are very large yellowish wedge shaped and white from inside. Mainly two varieties white fleshed and red or pink fleshed are available in India. Pummelo is preferred to plant in homestead.

### Climate

Pummelo is an essentially tropical citrus fruit. However it is grown in warm tropical and subtropical climate where rains are fairly received. Pummelos can stand heavy rainfall.

### Soil

The soil requirement for pummelo is not very specific however soil should be well drained and medium in nutrient contents for better yield.

### Varieties

The named varieties of pummelo are: Kae Pan of Thailand and Buntan of Formosa.

### Propagation

Pummelo is a monoembryonic therefore it is necessary that it should be propagated by vegetatively. Air layering (marcottage) is commercially adopted method of vegetative propagation. The budded plants of pummelo are usually raised on vigorous rootstock like Jatti khatti and Jambheri.

### Planting

It is similar to grapefruit.

### Cultural Practices

Almost all cultural practices for raising pummelos are similar to grapefruit.

### Harvesting and Yield

The normal season of cropping is from January to March in north India and September to November in South India.

About 100 fruits per tree is the average yield of pummelo.
Insect pests of Citrus Fruits

**Lemon Butterfly (Papilio demoleus Linn)**
It is the worst leaf destroying pest in nursery. It feeds on almost all citrus species but has a preference for sweet orange. The tender leaves are attacked from the margin inwards reaching the midrib. Lemon butterfly appears in April and August September in Punjab. The appearance of this pest in Andhra Pradesh is during July November and June July in Gujrat.

Whiteflies
Among many species Dialeurodes citri Ashmed whiteflies and Aleurocanthus woglumi Ash blackflies are the most destructive. The former is a minute in size and pale yellow with dark red eyes whereas the adult of later wooly whiteflies are distinctly more yellow than other. They remain hiding on the under surface of the leaves during day time. Both nymphs and adults suck the sap of leaves and reduce the plant vigour. Severely infested leaves become pale yellow to brown and later they curled and shed. Flowering and fruiting are affected very badly. Whiteflies may encourage the incidence of red scale and which collect under the wool of the whiteflies to avoid light. As such control of white flies is very difficult. However in nature lady bird beetle (Brunus saturalis) feeds on eggs and larvae of citrus whiteflies. Mealy bugs (Pseudococcus spp.) Mealy bugs are polyphagous pest. In citrus species especially limes lemons and sweet oranges are main target. Besides they feed on cactus and begonia. They are most serious pest in many parts of India. The adult female is wingless with a flattened body having short waxy filaments while the male is winged with no mouth parts and long antennae and is rarely seen. The nymphs are also covered with white waxy coatings and are amber coloured. The nymphs and adult females suck the sap from the underside of the leaves and at the base of the fruit near the stalk end. The plant growth is arrested leaves flowers and newly set fruits are shed. Ants aid in the spread of the mealy bugs which are attracted by the honeydew secreted by mealy bugs. The sooty mould develops on honey dew which adversely affects photosynthesis.

Aphids
Very common species of aphids which attack citrus crops in India are Aphis citricidus Kirk, Toxoptera citricidus (Kirk) Myzus persicae Sulzer (peak green aphid) Toxoptera aurantii Fonscolmbe (Citrus black aphid) and T. citricola (Citrus brown aphid) Aphis gossypii (cotton aphid) Aphidula pomi de Greer (apple green aphid).
Aphids are found in clusters over the tender parts of the plant (leaves new shoots flower buds). The incidence of aphids is highest in winter and rainy season. They suck the sap from tender parts which fade and become blighted. They also secrete a sweet honey like substance which attracts the ants and develops sooty mould on it. Aphids also act as a vector of virus disease.

**Control Measures**
Spray the trees with Malathion (0.05%) or phosphamidon (0.025%) or Katin (0.1%) or Rogor (0.3%). There is no insecticide which can control aphids as vectors of Tristeza virus because aphids transmit the virus in much shorter time than any insecticide could kill them. They are also migratory in habit and hence defy chemical control.
There are may natural enemies of aphids viz. lady beetles syrphid larvae lace winged flies any hymenopterus parasites destroy large population of aphids.

**Mites**
Among several species red mite (Parate tranychus citri McGrego) is found infesting sweet orange lemon grapefruit and acid lime. The green mite (Tetranychus spp) also infest citrus crops. They feed on
leaves tender fruits and green bark. The underside of leaves are tainted red and the leaves twigs and fruits get deformed due to sucking of the sap by mites. Severe infestation causes leaf and fruit crop.

**Scale Insects**

Several species of scale insects are found feelings on citrus. They suck sap from leaves and tender shoots. While sucking sap they inject toxic saliva. Affected twigs dry leaves and fruits drop down and if fruits remain on the tree they are in deformed shape. Not only this sooty mould fungus develops on honeydew excreted by scale insects affecting the photosynthesis activity of the leaves.

The scales are mainly of two types such as armoured and unarmoured or soft scales. Armoured scales secrete a waxy armour which provides protection to them. Unarmoured or soft scales have tough covering of the body. Armoured scales are: Citrus red scale (Aonidiella aurantii M) Florida red scale (Chrysomphalus aonidium L.) Glover's scale (L. gloverii Pack) purple scale (Lepidosaphes beckii Newm) Chaff scale (Parlatoria pergandii Comstock) whereas unarmoured or soft scales are cottony cushion scale (Icerya purchasi Maskell) soft brown scale (Coceus hesperidium L.) Black scale (Saissetia oleoe Bern) Waxy scale (Ceroptastis floridensis Com.) White scale (Pinnaspis aspidistrae S). and Arrow head scale (Unaspis yanonensis)

**Nematodes**

They affect growth of citrus trees by retardation of plant height size of leaves number of roots is reduced and later symptoms of tree decline are noticed.

The important nematodes affecting citrus are: citrus root nematode (Tylenchulus semipenetrans Cobb) Reniform nematode (Rotylenchulus reniformis) Blurrowing nematode (Radopholus similies Cobb) lesion nematode (Pratylenchus coffeae T. Goodey) Root knot nematode (Meliodogyne afriedane Whitehead) and Lance nematode (Hopdlolaimus indicus Sher).

**Citrus Fruit Breeding**

During its long history citrus has given the world numerous varieties both by open pollination bud sports and of recently by controlled pollination and artificial induction of bud variation. Breeding of superior cultivars possessing desired features is a continuous process throughout the world.

**Aims of Citrus Breeding**

The general objectives of citrus breeding mainly fall under 3 classes as follows:

**Related to Fruit Characters**

The prime objective of the citrus breeder is to obtain an excellent desert quality fruit. In addition to this the fruit should have few or no seeds suitable shape and size meeting the commercial requirements good shipping and keeping qualities attractive rind colour firm texture to meet the canning industry requirements e.g. grapefruit citron and oranges high juice colour for juice and mixed drink purposes and standard vitamin C content.

**Related to Tree Characters**

Compactness vigour productiveness disease and pest resistance cold hardiness adaptability to various agroclimatic conditions congeniality with rootstocks and better coverage with early mid and late varieties.

**Related to Rootstocks**

The obtain rootstock adaptable to different and adverse soil conditions resistant to trunk and root diseases high compatibility with the scion and high proportion of nucellar embryony. At the same time to obtain rootstocks which do not impart vigorous growth on the part of scion so as to make the scion to bear fruits of coarse texture and insipid taste.
The citrus seedlings being perennial in nature as a general rule take longer time to come to bearing usually not less than 5-6 years. However, this period can be reduced to a maximum of half by top working the seedling on an old tree. Further the trees are too expensive to produce and to test under different agroclimatic conditions.

**Polyembryony**

Polyembryony is peculiar to citrus. A normal embryo the resultant of male and female gametes union no doubt is present in the seed. In addition to the zygotic embryo one or more sometime as many as fifteen additional embryos developing from the nucellar tissue called nucellar embryos are found in the embryo sac. More often the zygotic seedling is crowded out by the vigorous nucellar seedling comes out from a vigorous nucellar seedlings. So even if a seedling comes out from a seed one is not sure whether it is a zygotic seedling. To obtain large number of hybrids the citrus breeder should select a seed parent known to be either monoembryonic or low in polyembryonic tendency. However, unfortunately all the economic Citrus species are polyembryonic except a few which greatly restricts their choice and complicate the procedure required to attain the desirable objectives.

**Sterility**

Sterility is the absence of capacity for gametic or sexual reproduction. Prevalence of high generative sterility is obviously a serious hinderance to the use of a variety in hybridization. Complete pollen sterility is particularly troublesome when (as in the Navel oranges and the Satsumas) the proportion of nucellar embryos is very high. Sterility often leads to the production of seedlessness. But this unfavourable effect of seedlessness on the fruit setting will be a serious hinderance to the production of valuable new seedless varieties. The general advantage of sterility in citrus is the production of seedless or near seedless fruits.

**Breeding Method**

There are four methods of breeding adopted in Citrus (i) Introduction (ii) Selection (iii) Hybridization and (iv) Mutation.

**Introduction**

This method involves the introduction of types from another region. It is usually attempted when the existing germplasm is felt unsuitable or lack some desirable character or merely to enrich the existing germplasm or to incorporate new blood in the existing germplasm by hybridization. Sometimes to meet the immediate need as a stopgap arrangement also this method is adopted. Nowadays this method is more often employed. A great exchange is going on between different countries.

During the beginning of this century India introduced mainly from U.S.A. some grapefruit varieties like Marsh Seedless Duncan Foster Thompson sweet orange varieties like Washington Navel Valencia Hamlin Pineapple etc. mandarin oranges like Kinnow Cleopatra Clementine etc. lemon varieties like Lisbon Eureka Villafranca etc. Even now India is actively considering the introduction of some more exotic types from other countries like Japan USSR both to enrich the existing germplasm as well to utilize them in hybridization programmes.

**Selection**

Breeding by selection is a search for superior form from a lot without any attempt to control their origin other than by choice of seed parent or choice of a tree as a material for a bud selection. Selection also plays an important role in isolating the superior types from a hybrid populations obtained by hybridization. The variations among citrus have arisen by hybridization mutations bud sports etc. From this lot man has selected superior types all through the ages and maintained them under cultivation. The process of such selection has gained considerable impetus with the introduction of vegetative methods of propagation. Even at present this method is employed in selecting superior types as per the objectives by screening from a lot
of collected germplasm. This involves the survey of different areas, collection of germplasm, raising the germplasm at a place, studying their performance for a considerable time and finally selecting a superior type.

**Hybridization**

Planned hybridization, though quite laborious and time consuming, has an important role in solving today's problems of Citrus Industry in the country. This fact can amply be realised by the performance of a large number of hybrids produced in U.S.A. Essentially hybridization is followed to create new types by reshuffling the genes in the existing germplasm. For any planned programme of hybridization, a collection of the genetic stock (germplasm) is very essential. The available variations should be located and brought together in one or two centres and utilized for hybridization. Hybridization essentially involves the controlled crossing of two genetically different parents to obtain a desirable type. In hybridization the breeder has control over the origin of new forms and choice of parents.

Realizing the importance of hybridization improvement of the Citrus varieties, U.S.A. has attempted hybridization on a large scale during the early part of the century and reaped a considerable success in obtaining a good number of promising hybrids. Besides U.S.A., other countries like USSR, Java, Philippines, Spain, Australia have also attempted breeding in Citrus with varying success.

**Mutation Breeding**

This method involves the artificial induction of variation by radiation. Bud variation is an abnormal variation in stems, leaves, and fruits that are capable of perpetuation through bud propagation. Such variations arise in the somatic tissues of the plant and frequently are termed as bud sports or bud mutations. Bud variations originate first as single changed cells which may develop into fruits, limbs or entire tree depending upon the place of origin of such cells. These can be identified by colour, size, shape, texture, rate of growth or other physical characteristics. Many of the fruit variations in the Citrus have been the result of individual fruit variations in otherwise normal trees.

As a rule, the limb variations are usually spotted easily by the appearance of their fruits, but occasionally by characteristic shape, size, and colour of the leaves.

Entire tree variations are rather commonly found in old orchards which can be distinguished by their fruit and leaf characters or their habit of growth. Since the fruit is the most important one, most of the entire tree variations have been spotted by their abnormal fruiting characters.

There is ample scope for the citrus breeder to spot out the desired bud variation and perpetuate it vegetatively notwithstanding the fact that majority of these bud variations are worthless.

**Choice of the Procedure**

The choice of procedure is very important in the improvement of Citrus varieties. Different procedures have to be adopted for achieving different objectives with different forms. Thus with monoembryonic species like pummelo (Citrus grandis) selfing and crossing of selected parents is advisable. However, to create variability, X-ray or other such treatments may be adopted. While with polyembryonic varieties, the procedure varies with the objective. If new varieties of similar to existing ones are desired, e.g., to prolong the season of variety or to have a variety with less prone to the incidence of granulation, one has to search for probable somatic variation in the variety or group of varieties. On the other hand, if the aim is to produce new varieties basically different from the existing ones, hybridization between the parents not closely related is the best method.

**Cytogenetics**

Virtually all cultivated forms of Citrus, Fortunella, and Poncirus are diploid and the diploid number of chromosomes in these genera is 18.
Blossom Biology in Citrus

Knowledge concerning the blossom biology of Citrus and other related genera is an essential prerequisite for initiating a hybridization programme. Such knowledge also facilitates the adjustment of cultural operations in relation to flower emergence and fruit development. Blossom biology in Citrus varies with species, variety, place and even within a variety at a given place. Blossom biology constitutes blooming or flowerings period, flower bud differentiation, flower bud development, inflorescence, sex ratio, anthesis, dehiscence, pollen fertility and stigma receptivity.

Blooming Period

Different species and cultivars may normally have different blooming periods influenced by agroclimatic conditions. The range of difference among the species grown commercially however is comparatively small normally not exceeding two weeks. The Poncirus and Fortunella flower very late i.e. in June and July while most of the Citrus species flower in spring i.e. in March and April. The lateness of flowering in Poncirus and Fortunella is commonly attributed to their dormancy in winter and late initiation of growth in spring.

The principal blooming period for all commercial species of Citrus is early spring and usually lasts for about 6 weeks. Flowering in India usually occurs mainly from February to April in most of the Citrus species. However owing to the diversity in climate in India, Citrus species are observed to flower in other seasons also. In North India where there are distinct winter and summer seasons the sweet oranges as well as mandarins bloom only once in a year i.e. in March. However Sinha and Mallik reported that sweet oranges bloom twice in a year under Bihar conditions first in February March and next in June July. Naik reports that Sathgudi oranges in South India flower twice in a year from December to April and September to December depending upon weather conditions. In more even climates of Central and Western India oranges flower thrice a year at intervals of four months i.e. June October and February. Coorg mandarins have two distinct flowering periods one during March April (main season) and the other during September October (off season).

The lemon, lime and the citron are to some extent continuous bloomers particularly under tropical climate producing some flowers throughout the year though the spring bloom is the heaviest. It is not uncommon to find particularly in lime flowers, fruitlets developing fruits and mature fruits all at a given time. In Assam most of the lemon varieties flower throughout the year while some flower only once in a year. Hill and Rough lemon are observed to flower only once in a year (March April) while Genoa and Seedless lemon flowered early (January) and Nepali oblong flowered latest towards the end of February. Kagzi lime at Varanasi and Kanpur flowers twice once in spring and then in June July and Naik reported that limes are in harvest throughout the year in South India with a maximum in March April and July September in circars and Rayalaseema respectively.

Flower Bud Differentiation

Every vegetative bud in Citrus is a potential flower bud. Induction and differentiation are not seen outside however under a microscope differentiation of flower bud can be observed. The vegetative bud in Citrus is conical one with pointed apex. In fact the Citrus buds in general are nearly naked lacking the complex covering of protective scales generally found in temperate zone plants. The flower bud has a flattened apex. Flattening and broadening of the shoot apex along with two protuberences one on either side is the first indication of flower bud differentiation. Seven stages of development during the process of differentiation were recognized in sweet orange. Calyx differentiated first the Corolla then stamen primordia next and lastly pistil primordia. Cessation of vegetative growth is a prerequisite for induction. It is generally observed that new flush precedes the flower bud differentiation ordinarily in early spring.
Abbott reported in Pineapple orange flower bud differentiation as occurring in January in Florida. In Japan Valencia Late differentiates in late January. Blood Red and Jaffa orange Kaula mandarin and sweet lime in North India differentiate in January.

**Flower Bud Development**

In various forms of Citrus the complete development of bud lasts from 18 to 47 days. In sweet orange in North India a flower bud takes 18 to 22 days while in lemon it took 20 32 days. In sweet lime it takes 22 25 days.

The development of a flower bud in citrus is greatly influenced by the prevailing temperature. As the temperature increases the time taken by a bud to develop is reduced.

**Inflorescence**

Inflorescence in different Citrus species is of cymose type. Flowers in citrus are borne on two types of shoots one with leaves and the other without leaves. In true morphological sense there are no terminal buds in Citrus. The so called terminal bud is nothing but a pseudo terminal one. Reece called the former one as leafy inflorescence and the latter as leafless inflorescence. Leafy inflorescences are borne on new wood while leafless inflorescences are borne on oldwood. The distribution and intensity of the two types of inflorescences differ. Zidan reports that in Valencia and Naval oranges and Balady mandarins the percentage of leafless inflorescence is much more higher than that of leafy inflorescence. Leafy inflorescences are more productive than leafless inflorescences evidently suggesting that presence of leaves is essential for increased production.

**Sex Ratio**

Citrus produces two types of flowers viz. staminate and hermaphrodite on the same tree with varying intensities. The production of staminate and perfect flowers is greatly influenced by species season nutrition etc.

Kagzi lime produces more hermaphrodite flowers than Tahiti lime. In sweet lime the production of staminate flowers is more. Randhawa report low percentage of perfect flowers in different varieties of lemon except Malta Meyer and Italian lemons. The occurrence of high proportion of male flowers is seen in lemons and citrons. Higher production of hermaphrodite flowers in sweet orange cultivars is reported by Haribabu.

In the beginning of the flowering period percentage of perfect flowers is higher and gradually the percentage decreases as the season advances in different citrus species. Low temperature and relatively high humidity seem to be more conducive for the higher production of hermaphrodite flowers.

Nutrition also influences the production of perfect flowers. This has been amply demonstrated by girdling ringing and defoliation experiments. A positive correlation exists between the fluctuations of starch content of the shoots and the percentage of perfect flowers. Increased production of perfect flowers is obtained from the normal and shy bearing trees by judicious nitrogen application. Zinc deficiency results in low percentage of perfect flowers.

Leafy inflorescences produce large number of hermaphrodite flowers as compared to leaf less inflorescences.

**Anthesis**

Ordinarily in citrus the flowers open during the morning time. Many workers have reported that anthesis occurs between 9 A.M. and 12 Noon in citrus. Anthesis is influenced by different factors like temperature light position of flower bud type of inflorescence aspect of the tree etc. A definite effect of temperature on anthesis in different seasons has been reported but others ruled out the effect of temperature on time of anthesis. Terminal buds open earlier than the lateral buds. Flowers on leafless inflorescences open earlier than those on leafy inflorescence. Flowers on the shaded side of the tree have been observed to open later
than those exposed to sunshine.

**Dehiscence**

Dehiscence of anthers in citrus takes place at different times in some before anthesis and in others after anthesis. In the former category are included lemons while sweet oranges, sweet lime etc. come under the latter group. Low humidity and high temperature are found to influence the dehiscence of anthesis. High temperatures accelerate the dehiscence of anthers.

**Stigma Receptivity**

Oozing of a gummy substance on the stigmatic surface is the indication of stigma receptivity in citrus. In general the stigma receptivity in various citrus varieties starts 2-3 days earlier to anthesis and lasts 4 to 6 days after anthesis with maximum receptivity on the day of anthesis. Duration of stigma receptivity is influenced by prevailing weather conditions also. In a dry spring it is shorter than in a moist spring.

**Storage Longevity and Fertility of Pollen**

The storage and fertility of pollen grains play an important role in hybridization programmes. It is often necessary to store pollen in a fully viable condition so that it may be used subsequently for making crosses between plants whose flowering periods do not coincide. Besides properly stored pollen can be transported to far off places for utilization for hybridization even in the absence of male parent. Further in fruit trees which are self incompatible the stored pollen can be artificially applied to get optimum fruit set even in the absence of pollinizers.

Under field conditions the pollen soon loses its viability. However it can be kept viable for longer periods by proper storage. The citrus pollen dried over concentrated sulphuric acid and sealed in glass vacuum tubes at about 0.5 mm pressure can be kept in a viable condition for more than two months. Trifoliate orange pollen remains viable for 110 days when stored in a desicater over Calcium chloride and remains viable even at 5ºC.

For storage of Temple orange pollen a higher temperature (16ºC) accompanied by a high concentration of CO2 in the atmosphere is found to be ideal while for Shamouti orange both low temperature and Co2 increase the storage life. Kagzi lime and grapefruit pollen can be kept for 37-38 months at a temperature of 0ºC and 25 per cent RH.

Pollen storage by home freezer can be the most convenient method for storing pollen for short durations. Certain pollen diluents have been found to be very effective both in maintaining the viability and subsequently in the operation of pollination. Powdered milk (non fat) egg albumen and lycopodium are some of the pollen diluents. When pollen is stored with these diluents the viability is maintained at a higher standard.

Pollen fertility varies from variety to variety. Moreira and Gurgal noted the pollen fertility varying from 0-90 per cent in oranges 50-80 per cent in limes and lemons above 60 per cent in tangerins and over 80 per cent in grapefruit. They further found that species and forms with the highest degree of polyembryony had a high percentage of viable pollen. Though the converse was not always true.

**Pollen Germination**

The germination of pollen grains in artificial solutions varies greatly in citrus. Temperature also influences germination.

Nagai studied pollen germination in some varieties of citrus and used 20 per cent solution of cane sugar with a trace of Japanese isinglass the germination ranged from 16 per cent in Valencia to more than 90 per cent in several other varieties. In Morton Citrange best germinations are obtained with 10 per cent sugar solutions with 58 g of agar agar in water. The germination of pollen from Meyer lemon in 15 per cent sucrose solution at 20ºC increases by the addition of 2, 4 D thiamin boric acid and IBA. Randhawa et al.
report 15 per cent sugar solution to be the optimum for germination of different lemon and citron pollen. In sweet lime 20 per cent sugar solution gives maximum pollen germination at 28°C.

Pollination and Fecundation
Self pollination and cross pollination seem to be about equally prevalent and also effective to bring about the formation of embryos and seeds in Citrus.

Natural self pollination in citrus is brought about by contact of anthers with the stigma by pollen falling or being blown against the stigma or by transfer of pollen by insects. Similarly natural cross pollination is doubtless accomplished by insects (entamophilous).

Fecundation in several species of Citrus occurs about four weeks after pollination. Petal fall and ovary remaining green are taken as the indications of fruit set in citrus. The success in fruit set is confirmed within 7 10 days after pollination. The intensity of fruit set is influenced by the time of flower opening type of pollination type of inflorescence. Early opened flowers have poor chance to set than those which open later. Dhillon further report 12 18 per cent fruit set by open pollination and 65 76 per cent by self pollination in sweet lime. Supplementary pollination and pollination with mixed pollen are reported to enhance the intensity of fruit set in citrus. In leafy inflorescence fruit set is more than in the leafless inflorescences.

Fruit Development
Citrus fruits develop very slowly usually taking 6 13 months to reach proper maturity. The duration from set to maturity varies from species to species cultivar to cultivar influenced by the condition of the tree availability of moisture temperature etc.

Torres reported 9 8½ and 8 month duration for sweet oranges lemons and mandarins respectively. Motial observed that sour orange took 245 days and Kagzi lime took 106 days for maturity.

Maximum growth of fruits in sweet oranges under Punjab conditions is between 4 and 7 months after set. The growth of fruits in Hamlin and Valencia Late is rapid upto middle of October (8th month) and end of November (9th month) respectively. Subrahmanyam reported active growth in limes accompanied by cell division and enlargement upto 90 days from fruits set growth lagging between 90 120 days during which the metabolic activities are at their maximum and rapid cell enlargement between 120 180 days.

The fluctuations in growth rates closely parallel the fluctuations in soil moisture. More stable size oranges can be grown under irrigation provided uniform moisture content is maintained throughout the rapid growth period. Moisture deficit during the period of development especially if accompanied by high temperatures retards the rate of growth particularly in early stages of development.

There is close relationship between the time of flower opening during the blooming period and its ability to grow into a fruit. The flowers opening around the middle of the blooming period have better chance to become fruits than those opening either early or late. The size and growth rate of citrus fruits is closely related with size and number of leaves per fruit on a given branch.

Suitable Climate
Climate is a deciding factor about success or failure of a given crop at a given place. Therefore one should give utmost importance to it. Most of the cultivated citrus fruits are indigenous to tropical rain forests of Southern China Cochin China and certain islands of the Malay Archipelag. Broad flat leaves lack of thickened cuticle limiting transpiration sunken stomata weak root hair development naked buds and absence of a regular dormant period (but cessation of growth is essential) amply demonstrate their origin from the tropical rain forests. Although the Citrus species have originated in the tropical regions their performance is best in subtropical environment hence they are mostly categorised under subtropical fruit crops. Nevertheless commercial citrus cultivation extends right from tropics to temperate regions. The citrus belt of the world covers a wide range of area in latitude. Anywhere within this belt at relatively low
attitudes citrus can be grown provided such other conditions like soil and water are favourable. However, the performance of citrus grown under different climatic zones varies accordingly. Fruits from strictly or absolutely tropical zone are usually inferior while those from temperate zones are frequently subjected to low temperatures. On the other hand, the fruits from subtropical regions excel those from other regions. Thus, it is clear that although the range of citrus belt of the world is vast, the actual and strictly optimal area for commercial cultivation of citrus is very much limited.

Influence of Climatic Factors

Temperature

Among the climatic factors, temperature is the most potent factor influencing the performance of citrus. Generally speaking, citrus endures both maximum and minimum temperatures up to an extent. The endurance varies with different species.

Maximum temperature: The maximum temperature that citrus can endure may be about or slightly higher than 50ºC. Sweet oranges are being successfully grown under temperatures up to 46ºC in Deccan plateau of India and even up to a temperature of 52ºC in Northern Rajasthan, Western U.P., and Punjab. The maximum temperatures injurious to citrus plants are seldom reached except in very limited areas. Under higher temperatures, leaves, buds, flowers, and young fruits, particularly of lemons and navels, get scorched, while young twigs show injury. The fruits on the outside of the tree canopy, especially of sweet orange and mandarins, may get cooked to some degree and rendered worthless. Hot summers cause sunburn of fruits in Punjab. When fruit ripens in hot weather, it soon passes from maturity to granulation. The injury by extreme temperatures gets aggravated by low humidity and high winds. Fruit set is low under high temperatures at the bloom. Young and newly set fruitlets dry up due to high temperatures. Extreme hot and dry weather during the months of May and June causes shedding of half-developed fruits, June drop.

Minimum temperature: Although the minimum temperature that can be endured by citrus trees varies considerably depending upon the species, varieties, condition of the tree, duration of cold period, and other accessory climatic conditions, any temperature below freezing (0ºC) is dangerous, especially when it persists long enough. Thus, the tree and fruit might endure a very low temperature of 7ºC or less for a short period without showing injury, whereas if temperatures from 3º to 4ºC continue for a longer period, they are considerably damaged. Flowers and young fruits are more sensitive to frost conditions and shed in very short periods of low temperatures (even slightly below 0ºC). Dormant trees are less prone to frost damage than those which are in active growth phase. Graft and budding areas are more vulnerable to frost.

Frost injury: Webber lists the various Citrus species in a descending order to frost sensitivity: Citrus medica (citron), C. aurantifolia (acid lime), C. limon (lemon), C. paradisi (grapefruit), C. grandis (pummelo), C. sinensis (sweet orange), C. aurantium (sour orange), C. reticulata (mandarins), Fortunella spp. (Kumquats), and Poncirus trifoliata (Trifoliate orange). The range is thus from the citron of the tropics to trifoliate orange of temperate zone. However, the difference from the species to another is very small but all are seriously injured if the temperature falls to below 9ºC (3). Even trifoliate orange which is said to be the hardest in most winters may seriously be injured by early freezes preceded by unusual high temperatures in the early fall. Trifoliate orange requires low temperatures to enter dormancy and high temperatures to break dormancy. Thus it escapes from spring frosts and late winter frosts. Kumquats follow the trifoliate orange. While others like grapefruits, sweet oranges, mandarins, and sour oranges get injured by late winter and early spring frosts due to their tendency to start bud growth following a few days of warm weather. Lemons and limes, due to lack of dormancy even in the winter, are readily subjected to winter injury as they have new foliage, flowers, and young fruits at almost any time.

The seedlings of sweet orange are able to endure more cold after they have reached bearing age than budlings of the same age. It has also been noted that seedless cultivars are more cold hardy than seedy
cultivars. This is attributed to a nutritional phenomenon wherein mineral nutrients are translocated to the developing seeds thereby leaving the twigs somewhat deficient temporarily. Very tender foliage or flowers are injured by low temperatures below 0°C. As the leaves mature they become less prone to frost injury probably due to accumulation of mineral nutrients and photosynthates in the leaf tissues. When the tissues reach the freezing point the fruit gets damaged. They show injury after exposure for shorter periods about two hours to air temperature 2°C. However individual fruits vary wildly in this respect depending upon size location on the tree rind thickness and initial warmth of the fruit. Mature and dormant trees have been reported to survive an exposure of 10 hours to low temperature below 4°C and of one and half hour to 9°C. Young trees may be killed outright by a single severe cold spell because of their thinner bark and low degree of tissue maturity. Healthy trees free from mineral deficiencies pests and diseases endure cold much better than the unhealthy and weakened ones.

Growth temperatures: The temperature range within which the citrus tree is able to grow develop and fruit is 14–40°C. However the best growth and performance occurs around 32°C or within 29–35°C. Fruit maturation including production of sugars and development of rind colour reach its highest perfection in the lower range of growth temperatures.

The minimum growth temperature required by different species of Citrus varies considerably. Grapefruits require less minimum growth temperature than Calamondin trifoliate orange and Citranges. At a maximum temperature of 38°C grapefruits performed poorly indicating this temperature as lethal to grapefruits. No growth of any part of the tree occurs at and below the vital temperature viz. 13°C. Under more uniform temperatures limes and lemons flower throughout the year with varying intensities particularly in the coastal areas. However this tendency is evidently inhibited by high temperatures in the hot interiors.

The amount of heat received during the growth season is more vital than the maximum temperature. A heat unit is taken as a degree above 13°C daily mean temperature. If the average daily temperature for a month is 13.3°C when the vital temperature of 13°C is subtracted from this 0.3°C is left as a remainder which on multiplication by the number of days in the month gives the index of total available heat for that particular month. Similarly the heat index is obtained for each month and these added together give the available heat index for the entire growing season of the year. Heat indices of the growing season have been calculated for some areas in United States as follows: Grapefruit: 5 617 6 781 Washington Navel oranges: 2 706 3 462 Valencia oranges: 2 672 lemons: 1 854. In India no such heat indices are calculated so far except for Allahabad. Allahabad probably has about 5 700 heat units in the warmest six months. While determining the most satisfactory regions for certain varieties the indices of available heat may be employed.

Relative Humidity
Atmospheric humidity has a greater role in the performance of citrus. In general low humidity gives good colour and external appearance whereas high humidity favours thin skinned juicy fruits which are smaller in size but high in quality. Citrus fruits grown in partial shade excell those grown without shade in their uniformity in size smoothness texture of skin and attraction. Fruits grown near coastal areas tend to be more spherical than those grown in the interior (12). Low humidity promotes transpiration and loss of water resulting in fruit abscission.

Disease infection is favoured by high humidity. As such desert areas are remarkably free from diseases like gummosis canker etc.

Rainfall
Proper distribution of rainfall is more important than the total rainfall. An annual rainfall of 500 mm is considered inadequate while 700 mm rainfall is said to be adequate provided it is favourably distributed.
An annual rainfall of 1250 to 1850 mm is generally regarded as sufficient. Unevenly distributed rainfall may be supplemented by additional irrigation despite heavy rainfall. Best quality fruit grows in semiarid subtropical regions with less than 500 mm of rain when orchards are irrigated. Under such conditions especially with warm days and cool nights the fruit acquires a good colour even on the tree itself whereas in the humid tropics even ripe fruit remains green. However heavy rainfall in the two months before harvest influences the quality of citrus fruits by reducing T.S.S. and acidity as observed by Sanchez in the case of Clementines.

Winds
Exposure to strong winds whether hot or cool is harmful. Therefore wind breaks should be provided in windy districts. Heavy gales are harmful to citrus trees and flowers and young fruits are easily blown off therefore shelter belt trees should be planted in regions where stormy winds are prevalent.

Altitude
Altitude in general is of importance only as it influences temperature. The great commercial citrus areas of the world are located mainly at moderate elevations ranging from slightly above sea level to 450 750m. In India citrus fruits are grown from sea level to an elevation of 1500 m in California 700 m in Spain upto 250 m although in South East Asia trees flourish at altitudes upto 2000 m. Although citrus fruits in tropical countries may be grown at altitudes from sea level upto 1800 m or more the culture becomes hazardous at such higher elevations.

Climatic Requirements of Different Citrus Species
In general citrus fruits can be grown from temperature to tropical regions under moderate temperatures and rainfall upto an elevation of 2000 m above sea level. However there is considerable variation among different Citrus species with respect to their climatic requirements.

Sweet Oranges (Citrus Sinensis Osbseck)
Sweet oranges require a dry and arid conditions coupled with distinct summer and winter seasons with low rainfall like those available in Punjab U.P. Deccan regions of Maharastra some parts of Gujarat northern districts of Andhra Pradesh. Under these conditions superior quality of sweet oranges are produced. In an atmosphere of high humidity and heavy rainfall the sweet oranges produced are of thin and smooth skinned with abundant juice. Such fruits have poor keeping quality and inferior taste. Further under heavy rainfall areas trees are prone to the attack of various diseases and pests. Therefore the cultivation of sweet oranges should be recommended in the drier and arid regions of India with a rainfall well under 700 750 mm with well defined winter and summer seasons and fairly wide variation between the day and night temperatures for under such conditions the trees grow well and yield fruits of excellent quality.

Mandrin Oranges (Citrus Reticulata Blanco)
Mandarin oranges (Santras) prefer slightly higher elevations and tracts with relatively higher humidity. They grow well in submontane tracts with elevation from 600 1050 m and rainfall ranging from 75 250 cm. They also grow and fruit well along with sweet oranges in the dry tracts of Deccan at altitudes between 450 750 m with a rainfall range of 50 75 cm and temperature range of 5 45ºC. One of the largest and most important centres of santra cultivation in India lies in this area. However santra does not grow well in the humid plains of South India Bengal and Bihar at attitude below 300 m. Except in heavy rainfall areas such as Assam Coorg etc. santras elsewhere are invariably grown under artificial irrigation. Santras tolerate more humidity in summer and winter season than sweet oranges. So they can be grown successfully in all tropical parts of India as well as in peninsular India in the submontane regions of North and Eastern India at elevations between 600 and 1050 m with a rainfall ranging from 75 250 cm.

Acid Lime (Citrus Aurantifolia Swingle)
Acid lime (sour lime  Kagzi lime  Mexican lime) being tenderer to frost than most other citrus fruits requires tropical climate for its successful performance. Situations which are warm  moderately humid free from strong winds and frost are ideally suited for its cultivation. It grows successfully even up to elevations of 900 m above sea level  provided the humidity in these regions is not high. In the more humid areas of Assam and West Bengal where the rainfall is above 125 cm  the lime becomes highly susceptible to citrus canker  which makes the trees unproductive and short lived. Commercial cultivation of acid lime becomes risky in Northern India  where the temperatures occasionally fall below the freezing point. Acid limes thrive well in West and South India  where frosts are unknown and the annual rainfall does not exceed an average of 75 cm.

Sweet Lime (Citrus Limettioides Tanaka)
Unlike acid lime  sweet lime can be grown under a wide range of climatic conditions. It is more hardy than acid lime and can withstand frost conditions better. It grows well under drier conditions of Northern India than under the equitable climate of South India. It can also be grown successfully at higher altitudes in Assam. Sweet lime is commercially grown in Punjab and Madras while in other parts of India it is limited to home gardens only.

Type of Soil
Soil is an important natural factor which determines the success or failure of a crop. Besides providing anchorage to the plant  soil furnishes water and nutrients for its growth and development. For good performance citrus requires a deep  well drained soil  free of excess salts with fair humus content. Though citrus can be grown on practically all types of soils  however  in view of the high oxygen requirements of its roots  light sandy to medium loam soils are considered best. The effect of following properties of soil on the growth and development of citrus will be helpful in selecting the proper soil for citrus cultivation.

Water Drainage
The citrus may be grown on various types of soils provided the sub  soil drainage is good because water drainage is more important than any other factor  for citrus roots have high requirements of oxygen because of lack of root hairs and accumulation of free water in the root zone results in poor aeration hindering the root lets to function. Under prolonged conditions of poor drainage  progressive injury and death of roots occur  leading to decreased performance of the tree as a whole. Resistance of the roots to root rot and other adverse soil conditions also gets reduced under poor drainage conditions. On the other hand  the performance of citrus is exceedingly well in sandy soils due to good drainage conditions provided sufficient nutrients are supplied. Sticky heavy soils through which water does not readily percolate should be avoided. Soils situated at lower levels adjoining the banks of irrigation canals  rivers  tanks etc. and those having a higher ground water table within a meter of the surface soil should also be avoided.

Depth of the Soil
Soils for citrus should be quite deep for easy penetration and spread of the root system. Studies have revealed that the roots of orange trees penetrate into the soil quite deep  while most of its feeder roots are situated in the first meter of the soil. As such any soil less than 2 to 3 metres in depth should be discarded. Deep well drained soils with no impervious layers  allow good depth for root development producing trees of standard size  heavy yields and long life. Conversely shallow soils  whether shallow because of hard pan layers in the subsoil or of water table produce substandard trees with short life span and poor yields. At the same time the soil should permit penetration and retention of water up to a depth of 2 meters. Molenaar gives 120 cm as the depth to which citrus will extract available soil moisture from deep well drained soil.
Nature of the Subsoil
Hayes noted that nature of the subsoil is more important than that of a surface soil because it effects the depth, drainage and fertility of the soil and ultimately the performance of orchard trees. Soils with hard pan within 2 metres of the subsoil due to either calcium carbonate concretions or clay should be avoided as they affect both the permeability and aeration of soils. The depth of the hard pan in the soil often decides the depth of active root system and also the age to which the tree decline starts. Greater the depth of the impregnated layers less is the tree decline. The existence of hard pan or calcium carbonate concretions in the subsoil is responsible for the tree decline in most of the soils of Andhra Pradesh and Punjab. High proportion of calcium carbonate and the presence of hard pan layers are therefore hazardous for successful citrus cultivation. However the heavy soils of Nagpur underlaid with a murrum (partly disintegrating rock) layer which provides a good drainage are quite suitable for citrus cultivation especially for Nagpur Santra.

Presence of lime in moderate amounts is good for citrus cultivation as it is thought that this helps to the success of orchards. Lime in moderate amounts as found in orange growing soils of Madhya Pradesh and Deccan makes the clay soils more friable and fertile. However soils with large amounts of lime as found in some parts of Deccan being toxic and harmful to the citrus especially orange trees should be avoided. A high content of calcium carbonate in citrus soils of Punjab is believed to be an important contributing factor for deficiencies of zinc, iron and manganese. Soils containing more than 5 per cent per lime in any of the horizon upto 2 metres depth should not be selected for citrus.

Soil reaction
According to experiments conducted in California a pH value of 5.5 to 6.0 is considered to be an optimum for citrus cultivation as lower levels tend to increase leaching of lime and magnesium and higher levels are likely to reduce the availability of trace elements. Nevertheless citrus orchards continue to flourish on soils with pH values of 4.0 to 8.5 and even higher. Haas claims that citrus grow better in an acid than in an alkaline medium. However it is advised to apply sufficient liming material to prevent the pH value falling below 5.5. It is also advised that the sail pH value of every citrus orchard should be determined once a year.

Salts
Citrus tree health is adversely affected and it succumbs within a few years of planting as a result of malnutrition due to excess salts in the soil. Therefore soils in which the total concentration of salts exceeds 1000 ppm should be discarded for citrus cultivation. Even irrigation water some times contains high content of salts. So both soils and irrigation water should be tested for their suitability before selection. Kanwar found that soil salinity is one of the important causes of chlorosis in Punjab. Therefore before planting the trees it would be desirable to have the suitability of the proposed soil tested and appropriate reclamation measures be taken wherever necessary.

Type and Fertility of the Soil
Type and fertility of the soils are not as important as the aforementioned factors in citrus cultivation so long as the plant nutrients are supplied readily and frequently. However very light soils lacking fertility and water holding capacity should be avoided. Sandy and gravelly soils are suitable in the higher rainfall areas like the Khasi hills of Assam and Darjeeling for they provide good drainage. Heavy soils if well drained may produce good crops but increase the difficulty in cultivation. But stiff deep black cotton soils of fine texture which crack during summer are not suitable. Presence of high humus content in the soil is also necessary for the effective combination of mycelia and citrus root as they lack root hairs. The only actually unsuitable soils are heavy clayey soils extremely dry soils (except of course where
irrigation is practicable) and most soils with impermeable underground strata retaining stagnant water.

Soils requirement of different citrus species
Sweet oranges and acid limes grow well on a wide variety of soils from heavy clay to very light soils. Heavy soils under good drainage yield bumper crops while very light soils on the contrary due to lack of fertility and moisture produce low yields. In shallow soils the trees remain stunted and die in their prime due to malnutrition. Trees are particularly more sensitive to higher concentration of salts and cannot stand waterlogged conditions for any length of time. The ideal soil thus seems to be a medium or light loam with a slightly heavier subsoil with a depth of 2-3 meters and pH of 6.0 to 8.0.

Lemons grow and bear well in comparatively shallow soils. However, good aeration up to a depth of a metre or more is more essential for its successful cultivation.

Sweet lime can be grown on a variety of soils and is rather tolerant to defective soil conditions. However, it does best on well-drained deep loam soils.

Other citrus fruits like grapefruit pummelo grow well on deep well-drained free working sandy loams loams and silt or clay loams with the chief preference being for loose, open, sandy loams with good physical conditions. But heavy soils containing high percentage of clay which have a tendency to drain poorly and insufficient aeration are not suitable.

The most distinctive feature of pummelo is its relatively high tolerance to saline conditions which has been exploited in Thailand wherein pummelo is cultivated in unproductive coastal low lands around river belts and brackish marshy areas. It is believed in Thailand that the flavour and the quality of the fruit are enhanced by the salt though lacks experimental proof. This must be investigated and if found true then pummelo becomes a potential crop for coastal low lands particularly in tropical countries where climate moisture and salinity prevent the cultivation of other citrus fruits.

Mandarins grow on a wide variety of soils but ideal soil seems to be a medium or light loam with a slightly heavier subsoil. Shallow soils should be avoided. Rain fed santras tolerate more soil acidity up to pH 4 but a range of 5-8 is more ideal.

Citrus soils of India
Citrus fruits are grown on a variety of soils throughout the length and breadth of India right from sandy soils on the coastal areas to deep black soils of interior alluvial soils of Indo-Gangetic plains to laterite gravelly soils on hill slopes of Assam, Coorg and Wynad.

In Nagpur area mandarins are grown on a variety of soils. The typical black clay soils which crack on drying are quite common. The other types are medium black to brownish in colour with different textures. The soils in general are very shallow with a depth varying from a quarter of metre to more than a metre and are underlaid with a porous subsoil of murrum. As the soils are shallow frequent application of manures and fertilizers is highly essential to maintain high productivity levels. Evidently, the world famous Nagpur Santra performs excellently under such soil and subsoil conditions under which conditions the tight skinned oranges perform poorly due to micronutrient deficiencies. The pH of the soil ranges from 7.0 to 9.0.

In Coorg and Wynad tracts of South India Santras flourish well in deep but well-drained black and red loamy soils.

In Assam Khasi orange is grown in valley lands of submountane areas where the soils are of alluvial types and on the hills where the soils are mostly lateritic. Major citrus growing belts of Assam are sandy loam or clayey loam soil with pH 4.5 to 6.0 and with high organic matter content.

In Punjab and western Uttar Pradesh the citrus fruits are grown on Indo-Gangetic alluvial soils ranging from light to heavy.

In Andhra Pradesh citrus fruits mainly sweet oranges and acid limes are grown on a variety of soils on deep and shallow soils with rock or hard pan at subsoil level. The pH ranges from 6.5 to 8.8. The soils are
poorly drained and have other setbacks. Citrus is grown even under unfavourable conditions e.g. in Kurnool district. Although Naik condemned this area as unsuitable for citrus many growers feel that citrus in this area is more remunerative than any other crop. The same trend is followed in Anantpur district where citrus is indiscriminately planted in all types of shallow soils with meagre water sources. Yet many growers make reasonable profits from citrus orchards in these areas.

**Citrus Soils of Elsewhere**

In California the soils of different section are variable ranging from light sandy to heavy clay loams and in general are fairly productive. In Florida citrus fruits are grown on fine sandy loams which were originally occupied by native forests of hardwoods, oaks etc. (Hammocks) and are frequently on the banks of rivers and lakes on very sandy soils ranging from fine sands and sandy loams to coarse sands underlaid with clay (high pine lands) and on soils which are very shallow and underlain with lime stone rock (flat woods). In general the soils of Florida are acid.

In China citrus soils in general are sandy loams varying to clay loams. In locations where the soils are well drained the trees suffer from drought in the dry season. In other locations on level lands the trees are often planted on raised beds with drainage ditches between the rows to remove the excess water during heavy rains. The principal part of commercial citrus crop in China is produced in low lands adjacent to rice fields and sea where the tide water fills the ditches between the rows with very high water table.

In Japan most of the citrus orchards are on hill slopes. The nature of the soil varies from sandy soil of granite origin to clay soil. With low natural fertility soil are acidic in reaction. To offset coldness in winter citrus fruits are grown on shallow and poor soils under heavy fertilization.

When compared to other countries like U.S.A. USSR etc. the citrus breeding in India has started late and the work so far has not given any considerable success as in other countries.

**Work done in India**

At Poona College of Agriculture first attempts were made at hybridization in 1912, 1914 and 1918 however no success both for stock and scion for soil and climate adoptability was obtained. Afterwards there was a long gap in citrus breeding in India. However it was again initiated somewhere in 50’s. But no published information on the objectives, progress and achievements of citrus breeding in India are available except sporadic references here and there.

In order to achieve the above objects crosses between cultivars (local and exotic) of same species between different species (sweet orange and pummelo and lemon lime and lemon) and between different genera (C. sinensis and Feronia limonia Atlantis monophylla Fortunella spp.) were affected.

A large number of hybrid progenies were obtained as a result of the above crosses and these hybrid progenies were planted in the main field for studying their performance.

Among the lemon hybrid progenies which came to bearing within 2-3 years from planting 5 hybrids were described by Rangacharlu. However afterwards there were no published reports about the performance of the hybrid progenies not any indication of continuing the citrus hybridization programme at Kodur.

Bindra reported that out of 10 root stocks screened against citrus nematode Tylenchulus semipenetrans trifoliate orange and Savage orange (a hybrid between Poncirus trifoliata × Citrus sinensis) proved best. At Citrus Experiment Station Chetheli Coorg work on breeding for rootstock improvement is being carried out. From screening of Citrus germplasm trifoliate orange and sour orange appeared to be resistant to Phytophthora. Crosses were made taking Rough Lemon Rangpur Lime Cleopatra mandarin, Kodai Kitheli Kichili and Coorg mandarin as seed parents and Poncirus trifoliata as pollen parent. On screening of the hybrids and nucellar seedlings it was observed that all hybrids were resistant to Phytophthora while nucellar seedlings showed different degrees of susceptibility upon seed parents thereby showing that trifoliata imparts resistance to hybrids. At Saharanpur experiments conducted for the
last two decades revealed that the Hill lemon rootstock proved most compatible for Mosambi pummelo for Kagzi lime Italian 76 for Hill and Florida Rough for Rangtra mandarins.